

STEM EDUCATION IN CULTURE & CONTEXT

A Handbook for Educators



Acknowledgements

This handbook would not have come together without the generosity, insight, and commitment of the educators, researchers, and practitioners who contributed their time, ideas, and experiences to this publication.

I would like to thank all our contributors for sharing their reflections on STEM education, and for helping us understand how Science, Technology, Engineering and Mathematics can be made more meaningful when rooted in culture, context, and lived experience. Their contributions remind us that effective STEM education is not only about technical knowledge, but also about curiosity, problem-solving, creativity, and relevance to the communities in which students live and learn.

I am especially grateful to Dr Melissa Neo, Academic Planner at InsPIRE, Nanyang Technological University, Singapore, for lending her expertise and guidance to this publication. Her thoughtful input as Consultant Editor helped shape the handbook's focus and ensure that its ideas remain practical, accessible, and useful for educators seeking to bring STEM learning to life in diverse classroom contexts.

Finally, I would like to extend my appreciation to my team at The HEAD Foundation, and in particular to Hillary Loh, Managing Editor, for her careful stewardship of this publication. Her editorial direction, attention to detail, and commitment to the *Making HEADway* series have been instrumental in bringing *STEM Education in Culture & Context* to fruition.

Through this handbook, we hope educators will find ideas, strategies, and examples that encourage them to design STEM learning experiences that are not only engaging and rigorous, but also responsive to the cultures, communities, and contexts of their learners.

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STEM EDUCATION IN CULTURE & CONTEXT

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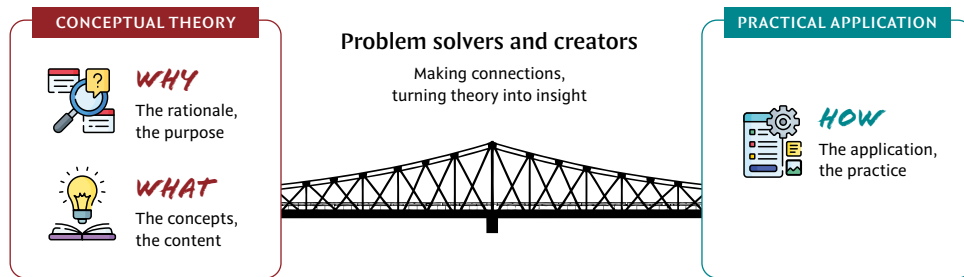
Preface

In the 21st century, technological breakthroughs and advancements drive the demand for a more proficient STEM workforce, resulting in discourse that is increasingly focused on the transformative affordances of STEM education. Structured well, integrated STEM learning can cultivate critical thinking, adaptability, technical literacy, creativity, and innovation, and empower students to tackle complex, open-ended, real-world challenges. The systemic shift towards STEM integration in the educational landscape, whether embedded within the core curriculum or through co-curricular initiatives, provides opportunities for students to contextualise their learning. By bridging conceptual theory with practical application, learners can discern the “why” (rationale) behind the “what” (content) and “how” (application), transitioning students from being passive consumers of information towards becoming problem solvers and creators.

This handbook is a practical companion for practitioners who believe that STEM is not just a collection of disciplinary knowledge and skills, but rather a dynamic culture with a unique ecosystem of its own, shaped by distinct characteristics, frameworks, practices, and societal values.



Bridging Conceptual Theory and Practical Application
Connecting *understanding* with *doing* to create real impact



At the heart of this ecosystem is contextualised STEM learning and problem-solving. By integrating cultural narratives, community beliefs, and regional realities into STEM lessons, this approach empowers students to be intrinsically curious and critically engage with and address local and global challenges.

Featuring ready-to-implement lesson plans and comprehensive customisable supporting materials, this handbook provides a diverse portfolio of contextualised lessons spanning early childhood through to higher education. The lessons showcase how practitioners and educators across Asia have integrated region-, school-, and/or community-specific challenges with actionable insights for short-term, single-day STEM initiatives, or long-term project- or problem-based learning.

In each chapter you will find:

Lesson objectives for adoption or adaptation based on your curricula needs

A lesson plan with detailed steps and instructional guidance

Pedagogical tips to facilitate inquiry, guide collaborative discourse, and scaffold complex tasks, etc.

Challenges and solutions to provide insights into potential roadblocks such as resource management and student learning difficulties

Teacher reflections such as on-the-ground experiences, lesson modifications for future iterations, and more!

“STEM is not just a collection of disciplinary knowledge and skills, but rather a dynamic culture with a unique ecosystem of its own, shaped by distinct characteristics, frameworks, practices, and societal values.”

Given that no two classrooms are identical, we hope that this handbook acts as a:

1. Conceptual foundation to try out integrated, contextualised, STEM lessons; and
2. Launch pad to modify, ideate, or pilot contextualised STEM lessons of your own, that draw out and strengthen student STEM competencies.

To guide your journey, the content has been sectioned into two parts:

- **Book I: From Frameworks to Familiar Spaces**
- **Book II: From Systems to Social Stewardship**

Learn about frameworks developed and enacted by STEM specialists and educators to support pedagogical practices such as inquiry-based learning, design thinking, and problem-based learning. Then, explore how to leverage easily-accessible everyday spaces such as the school environment and local community to anchor technical concepts in familiar real-world contexts. Guide students to recognise the complex, interdependent relationships between technological, environmental, and social structures through predictive modelling and systems-based thinking. Cultivate a sense of civic mindedness, to encourage students to leverage STEM competencies for ethical decision-making and sustainable contribution towards the resilience and wellbeing of their local and global communities.

Learning is deeply shaped by the values, stories, beliefs, and systems of knowledge within each community. Contextualisation of STEM lessons can aid students in:

- Recognising the relevance and application of knowledge to their immediate world;
- Boosting cognitive engagement and conceptual retention; and
- Appreciating how complex problems demand an integrated and interdisciplinary approach, through shared communal value and collaborative ways of thinking and learning.

Book I
From Frameworks to Familiar Spaces



Section 1: Models and Frameworks for STEM Instructional Design



Section 2: Immediate and Familiar Spaces as Sites of STEM Learning

Book II
From Systems to Social Stewardship



Section 3: Using STEM to Model and Understand Systems



Section 4: Cultivating Civic-Mindedness through STEM

“Learning is deeply shaped by the values, stories, beliefs, and systems of knowledge within each community.”

We hope that this handbook will serve as a supportive guide as you begin or deepen your journey of integrating STEM education as a cultural practice. It is our hope that the pedagogical frameworks and lesson plans detailed here will provide fresh perspectives that inspire spaces for collective inquiry, co-construction of knowledge, critical consciousness, and innovation; and instil in students the essential competencies foundational to a future-oriented and adaptive mindset.

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Contributors' Biographies



Dr Kessara Amornvuthivorn has led major education initiatives across Southeast Asia since 2005, drawing on 14 years of experience in the private sector and entrepreneurship. Her work focuses on advancing evidence-based policies to strengthen human resource development, especially in basic education. She has also supported nationwide education reforms in Thailand via research at the Teachers College.

She holds a PhD in Development Administration from the [National Institute of Development Administration](#) (NIDA), Thailand, and currently serves as Program Director at [SEAMEO STEM-ED](#), guiding regional research and capacity building in STEM education. From 2015 to 2023, she led the USD 35 million Chevron Enjoy Science initiative, which enhanced K–12 STEM education through partnerships with policymakers, universities, and educators. She currently directs the [Southeast Asian Teacher Education Programme](#), a regional collaboration with ministries of education and STEM institutions in five countries.



Dr Burin Asavapibhop currently works at the [Southeast Asian Ministers of Education Organization Regional Centre for STEM Education](#) (SEAMEO STEM-ED) as a Programme Manager responsible for STEM resources and capacity building. He has been with SEAMEO STEM-ED since January 2022. He was previously a professor in Physics at Department of Physics, Faculty of Science, [Chulalongkorn University](#), Bangkok, Thailand where he led an experimental high energy physics research group. He has been involved in several world class experiments such as the Compact Muon Solenoid at the European Organization for Nuclear Research, Switzerland, and the Jiangmen Underground Neutrino Observatory at the Institute of High Energy Physics, China.



Dr Ariel L. Babierra is an Associate Professor of Mathematics at the [Institute of Mathematical Sciences, University of the Philippines Los Baños](#). He obtained his PhD in Mathematics from [University of the Philippines Diliman](#) with specialisation in Approximation Theory. His work includes participation in curriculum and instruction committees for the Mathematics and Applied Mathematics programme and teaching a General Education course on Mathematics, Culture and Society. His training in quality assurance for curricular programmes led him to redesign courses to ensure alignment with programme and learning outcomes while incorporating soft and core skills even in highly technical Mathematics courses. In his free time, he can be found reading books about Mathematics or wandering fantasy worlds in books and role-playing games.

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Mdm Rosmiyati Bustami is a dedicated Geography educator at [Punggol Secondary School](#) in Singapore with nearly 30 years of teaching experience. She has continually driven innovation to make learning relevant, hands-on, and purpose-driven. In 2022, she and her Geography Unit were awarded the MOE Innergy (Bronze) Award for their Innovative and Sustainable Urban Farming project, marking a key milestone in their collective effort to nurture students as informed, concerned citizens who contribute meaningfully to a sustainable future.

Her efforts showcase the transformative potential of Geography education — when cross-disciplinary partnerships and real-world applications come together to equip students with scientific inquiry skills, technological literacy, and a strong sense of environmental stewardship.



Ms Shella Mae E. Catalan is a Biology teacher at De La Salle University Integrated School, where she has been shaping young minds for the past 10 years. Throughout her decade of teaching, she actively integrated innovative teaching strategies and experiential learning approaches, such as laboratory activities and STEM-based projects. A licensed professional teacher, she is set to further her academic journey by pursuing a Master's degree in 2025, aiming to enhance her expertise in Science education and bring new insights to her teaching practice. Her decade-long career and continued pursuit of academic excellence embody her mission to inspire, educate, and make a lasting impact on her students and the community.



Mr David Chak is a Malaysian educator and social entrepreneur dedicated to revolutionising education. He is the co-founder and curriculum director of [Arus Academy](#), a social enterprise that has impacted over 150,000 students and 100,000 teachers in Malaysia since 2015. A former [Teach for Malaysia](#) Fellow, David co-authored the Malaysian Year 5 Digital Technology textbook and writes on global issues and media literacy for a local Chinese quarterly magazine. His expertise is further enriched by several prestigious fellowships: the [Young Southeast Asian Leaders Initiative \(YSEALI\) Professional Fellowship](#), the [Acumen Fellowship](#), and the [Fulbright Hubert H. Humphrey Fellowship](#) at Vanderbilt University. He holds a bachelor's degree in Psychology with a minor in Computer Science from [McGill University](#) in Canada and a postgraduate diploma in education from the [Northern University of Malaysia](#).



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A Fulbright Research Fellow, she has published widely at national and international levels, and collaborated with UNESCO, the British Council, Australian universities, and the Sumitomo Foundation, Japan. She has presented papers globally and is the recipient of numerous awards, including the Distinguished Diversity Enhancement Award from Ohio State University (the only Asian recipient for the Minority Young Scholars Project), the Graduate Research Alumni Award from Ohio State, and multiple Gold Medals at ITEX and MTE for innovations in assessment systems, teacher education models, and STEM educational modules.

In 2020, she was further honoured with the International Recognition Award for her pioneering efforts in cultivating STEM entrepreneurs.



Dr Thanyaluck Ingkavara is a lecturer at the Faculty of Education, Naresuan University. She was previously a Mathematics teacher at [Naresuan University Secondary Demonstration School](#), Thailand. She worked with middle school students, where she helped them understand Mathematics as

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Ms Retna Widiyasrini is the Assistant Program Manager at [Prestasi Junior Indonesia](#), a non-profit organisation dedicated to advancing education in financial literacy, entrepreneurship, work readiness, and STEM. She leads the STEM education department, designing innovative, inclusive programmes that spark student interest and skills in Science, Technology, Engineering, and Mathematics.

With a strong passion for curriculum development, Ms Retna has spearheaded several impactful initiatives. These include JA RAISE, an AI and robotics-integrated curriculum adopted in four Asia Pacific countries; Street Code, which introduces basic coding to underserved youth; and Robocoder, a digital literacy programme tailored for students with cerebral palsy and other disabilities.

Ms Retna also manages STEM initiatives supported by global partners such as Microsoft, AWS, HP, IBM, Accenture, and the Caterpillar Foundation. Through her leadership, these programmes have expanded access to future-ready learning, reaching diverse student populations across Indonesia and nurturing the next generation of STEM leaders.



Ms Sooprawee Wuttisawat is a primary school teacher at [Starfish School](#), Chiang Mai, Thailand. She teaches English, Problem-based Learning, and Makerspace time. With 17 years of teaching experience, she possesses flexibility in instructional design and a deep understanding of the developmental characteristics of children at different ages. She places strong emphasis on fostering learner-centred education, ensuring that students take ownership of their learning. This approach equips them with essential skills and the ability to apply their knowledge meaningfully in real-life contexts.



CONSULTANT EDITOR

Dr Melissa Neo is a member of the [Multi-Centric Education, Research and Industry STEM Centre](#) (meriSTEM@NIE) research team. She is also part of the Nanyang Technological University's Institute for Pedagogical Innovation, Research & Excellence – Teaching, Learning, and Pedagogy (InsPIRE-TLP) unit. A passionate advocate for integrated STEM education, her contributions aim to bridge the gap between theory and practice. Dr Melissa has co-authored [Becoming a STEM Teacher: My Learning Journey](#) — a self-guided handbook designed to support educators on their path from novice to confident STEM practitioners. She has also served as a judge on several STEM capacity-building symposiums and played a central role in organising the annual Empowering STEM Education Professionals Programme. Her commitment towards creating impactful educational materials and learning experiences is further fuelled by her keen interest in classroom-based research on effective teaching strategies and best practices.



Introduction

Understanding & Applying iSTEM for the Classroom

Coined in the 1990s by the National Science Foundation, the acronym STEM (Science, Technology, Engineering, and Mathematics) has exerted significant influence on contemporary educational discourse over the recent decades, driving global institution-wide impact on educational policy and economic strategy.

While traditional school curricula historically compartmentalised these disciplines into rigid silos, modern STEM education — propelled by an increasingly automated, information-driven economy — has shifted towards an integrated approach. The motivation to integrate STEM is, in part, due to the contrast between the segregated structure of STEM within schools and the integrated STEM-based challenges students encounter underprepared as they enter the workforce.¹ As such, this pedagogical approach aims to cultivate an interdisciplinary mindset, enabling students to connect theoretical knowledge with the broader world, and to understand when and how to apply cross-disciplinary knowledge and practices effectively.

In this handbook, we define integrated STEM (iSTEM) as “the approach to teaching the STEM content of **two or more STEM domains**, bound by **STEM practices** within an **authentic context for the purpose of connecting these subjects to enhance student learning**” (p. 3).⁴

There are various interpretations of what integrated STEM (iSTEM) entails in the literature, offering diverse ways in which iSTEM is operationalised in educational settings. This presents challenges for educators seeking to implement iSTEM be it at the level of a class, unit, or lesson, due to the lack of a universally accepted understanding.

We highlight six characteristics of iSTEM adapted from Kelley and Knowles' 2016 framework, which are exemplified in the lessons highlighted in this book:

1. A complex, persistent, and extended real-world problem²
2. Interweaving the knowledge and processes of two or more specific STEM disciplines to solve the problem²
3. Engagement in engineering design or design
4. Establishing explicit connections between real-world contexts and STEM content
5. Engagement in authentic STEM practices (such as problem-solving with multiple solutions, evidence-based data collection and reasoning)
6. Development of 21st-century skills (such as critical thinking, equitable participation, and open mindedness towards diverse perspectives)³

Effective classroom practice of iSTEM relies on iterative engagement in planning, strategic execution, reflective practice, and refinement. To assist in managing this cycle, we outline some common instructional tensions and decision-making opportunities experienced by teachers.⁵ These considerations are intended to prompt deeper reflection on how you might enact iSTEM in your specific educational context.



Balancing curricular content with an integrative approach

Balancing the need to teach subject-specific content deeply and the importance of highlighting the broader interconnections between supporting disciplines. Choose which discipline serves as the primary anchor and which play a supporting role. One can still meaningfully integrate two or more subjects in a lesson to support student conceptual understanding and/or skill development. For example, to evaluate students' understanding of energy transfer (Physics — lead discipline), students build a mini turbine using blades of different shapes (Engineering design — supporting discipline) to measure the voltage output (Mathematics — supporting discipline).



Deciding on sole instructor, parallel teaching, or collaborative teaching efforts

The scope of STEM inquiry can be influenced by a teacher's expertise. When designing a lesson plan, reflect deeply on the complexity of cross-disciplinary knowledge and skills required to address the problem. Then, consider how collaborative instructional methods such as parallel teaching or co-teaching can be intentionally deployed to support student learning given scheduling constraints, student readiness, availability of instructional resources, and more.



Providing guided instruction versus student-directed learning

Open-ended inquiry and complete autonomy can be overwhelming. Students engaging in STEM for the first time frequently feel underprepared, encountering high cognitive load due to gaps in foundation knowledge and technical skills. To mitigate this frustration without diminishing the inquiry process, strategic scaffolds such as embedded time buffers can be put in place — to provide space for unguided trial-and-error, navigate design failures, and engage in iterative troubleshooting. Following this, guided instruction (such as a partially completed script for a coding task) can be provided to bridge the gap between open-ended inquiry and overwhelming frustration.



Encouraging collaboration while supporting individual student needs

Designing an iSTEM lesson that both cultivates a collaborative ecosystem and sheds light on the unique blueprint of individual learners can be challenging. By designing a real-world challenge that is too complex for individual students to solve, this encourages students to embrace diverse perspectives and skillsets to brainstorm solutions, divide problem-solving tasks, and collaborate to converge on an optimal solution. To support individual growth, differentiated roles and layered scaffolding can be tailored to students' skill levels and learning styles.

The interdisciplinary nature of iSTEM functions much like a pulley system, in which the individual disciplines serve as interconnected cords. When collectively pulled by teachers, students, and industry experts, these cords create the necessary leverage to enhance student understanding.⁴

In the same vein, rather than offering a prescriptive model, the presented considerations emphasise the need for continued exploration and empirical insight into iSTEM pedagogy.

This handbook hopes to support individual professional growth while encouraging a broader collaborative exchange within professional learning communities, by translating classroom experiences into research-informed findings and promoting shared inquiry with the wider educational community.



REFERENCES AND SUPPLEMENTARY READING

Journal articles:

1. Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research*, 110(3), 221–223.
2. Tan, A. L., Teo, T. W., Choy, B. H., & Ong, Y. S. (2019). The S-T-E-M Quartet. *Innovation and Education*, 1(1), 3.
3. Roehrig, G. H., Dare, E. A., Ellis, J. A., et al. (2021). Beyond the basics: a detailed conceptual framework of integrated STEM. *Disciplinary and Interdisciplinary Science Education Research*, 3, 11.
4. Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3(11), 1–11.

Practical insights, tools, and strategies:

5. National Science Teaching Association. (2025). *What does it really mean to integrate STEM?*
6. Markham, T. (2011, March 7). *Strategies for embedding project-based learning into STEM education*. Edutopia. George Lucas Educational Foundation.
7. National Institute of Education (2025, February 17). *Evaluating STEM success — Practical tools for engaged learning*.



Section 3

Using STEM to Model and Understand Systems

- 3.1 Drawing on Local Geometric Patterns to Introduce Mathematical Concepts
- 3.2 Secret Agents: Learning Cryptography Through Ciphers
- 3.3 Modelling STEM Solutions to Reduce Inequality
- 3.4 Combating Air Pollution in Lower Northern Thailand
- 3.5 From Shortage to Innovation: A STEM Hackathon to Tackle Singapore's Eldercare Challenges

Real-world challenges rarely exist in isolation, whether it concerns digital privacy protection, preserving and raising awareness for cultural heritage, or mitigating an environmental crisis. Instead, they are embedded in interconnected systems where culture, geography, and social structures play as much of a role as disciplinary knowledge and skills.

Adopting a systems lens to STEM involves guiding students to see the world not just as a series of fixed outcomes but rather as a set of interconnected, interacting variables. For example, when examining how agricultural burning contributes to air pollution in northern Thailand, students must move beyond basic scientific concepts such as chemical combustion, and recognise other contributing factors such as regional topography, economic pressures on farmers, and more. Similarly, when exploring encryption, aside from modular arithmetic, students must navigate the affordances and limitations of encryption and recognise the tension between individual privacy and collective security.

The lessons in this section will guide students to understand that STEM-based solutions are dependent on contextual variables and the ecosystem within which they exist.

When reading this section, consider:

- What is the key driver you would like to explore in this “system” (e.g., social value, industrial efficiency, etc.)?
- What boundaries might you wish to put in place to clearly define variables that are “inside” the lesson (i.e., variables that students will be analysing) and those that are “outside” the lesson to accommodate constraints such as time, prior knowledge, and more?
- What variables or constraints are non-negotiable and how might these shape the range of STEM solutions proposed?

3.1

Drawing on Local Geometric Patterns to Introduce Mathematical Concepts

Dr Ariel Babierra



INSTITUTIONAL PROFILE

Institute of Mathematical Sciences, University of the Philippines Los Baños

LOCATION

Los Baños, Laguna, Philippines

TYPE OF INSTITUTION

Tertiary and post-graduate institution

LESSON DETAILS

NUMBER OF LESSONS

4 lessons

DURATION

90 mins/ lesson

GRADE LEVEL

First- to fourth-year undergraduate students

SUBJECT/ DISCIPLINE

Mathematics, General Education

NO. OF STUDENTS/ PARTICIPANTS

35

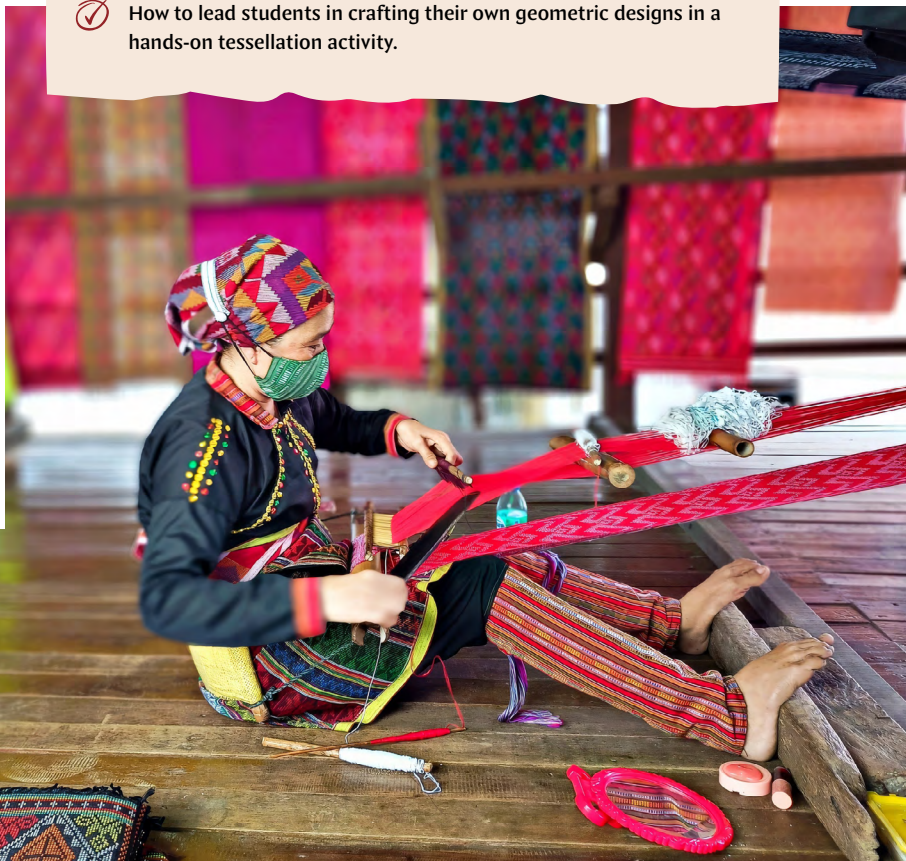
STUDENT READINESS

Mixed ability

How can we spot geometric principles in our daily lives? Take a moment to recall where you have seen them before, perhaps in an art piece or traditional craft. In this lesson, Dr Ariel introduced the concepts of symmetry and tessellation by discovering them in natural phenomena, man-made structures, and traditional tribal craft. Students applied theoretical knowledge in a final project by designing their own unique tessellations, creating a work of art using geometric principles.

In this chapter, we learn:





- ✓ How Mathematics can be integrated with aspects of culture, history, and art to deepen appreciation of its broader societal function and the significance of geometric patterns.
- ✓ The basic principles of symmetry and tessellation, including 2D rigid transformations.
- ✓ How to lead students in crafting their own geometric designs in a hands-on tessellation activity.



The origins of Mathematics are deeply embedded in the everyday activities of early societies. Mathematics evolved in response to the needs of local communities, cultural practices, and broader societal developments. Yet in today's classrooms, these rich and meaningful contexts are often lost among abstract symbols and standard content. With the emphasis on formulas, procedures, and generalised concepts, the local and cultural roots of Mathematics are frequently overshadowed.

In this General Education class for students of all disciplinary backgrounds, students examined real life items to identify recurring patterns and compare the geometric features across the various examples. Working in groups or as a whole class, they collaboratively explored the similarities among the designs, particularly the underlying structures that enable repetition. This activity served as a foundation for introducing mathematical concepts such as **frieze patterns** and **wallpaper groups**, allowing students to recognise and classify these patterns using formal Mathematical language.

In contrast to the Mathematics lessons of the past, students were tasked with researching the cultural or disciplinary significance of the patterns they examined. This included exploring the historical, artistic, or symbolic meanings within their respective communities. They were also encouraged to create original geometric designs inspired by local culture or personal experiences. These student-created works were shared through a classroom show-and-tell and displayed as part of a simple exhibition, transforming the classroom into a space that reflects both mathematical learning and cultural identity.

Topics covered in this lesson			
Geometric patterns in everyday objects 	Mathematics of tiles and tessellations 	How to create your own geometric wallpaper 	Geometric patterns in culture and society 

(left) Hand-loomed Yakan fabrics from Zamboanga feature geometric patterns that convey cultural and historical narratives

Understanding learning domains: Bloom's taxonomy of educational objectives

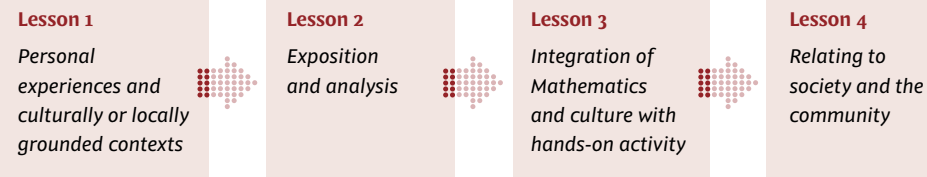
Dr Ariel references the learning domains created by Benjamin Bloom in the learning objectives below. Bloom's taxonomy is a model used for classifying learning objectives by level of complexity and specificity.¹

Guide: Incorporating cultural and societal contexts in Mathematics lessons

To make Mathematics more accessible, concrete, and relatable beyond subject-specific applications, **introduce mathematical content through culturally relevant contexts** rather than abstract definitions. This approach can begin with a scenario or local practice, followed by observation, discussion, and even simulation or role-play in class. In doing so, students encounter Mathematics as it naturally arises in the world around them.

To draw out a topic or capture students' attention, start the lesson with conceptual motivations that are more personal and familiar to students, to ground the topic in local cultural or community experiences. For students to better understand and appreciate the relevance of Mathematics in their daily lives, incorporate activities that cut across cognitive, affective, and psychomotor domains, and make explicit links back to societal or community-based contexts at the end of the topic to foster broader perspectives.

Here is a suggested lesson flow on incorporating culture and community into a Mathematics class. This can be adapted for any Mathematics lesson.

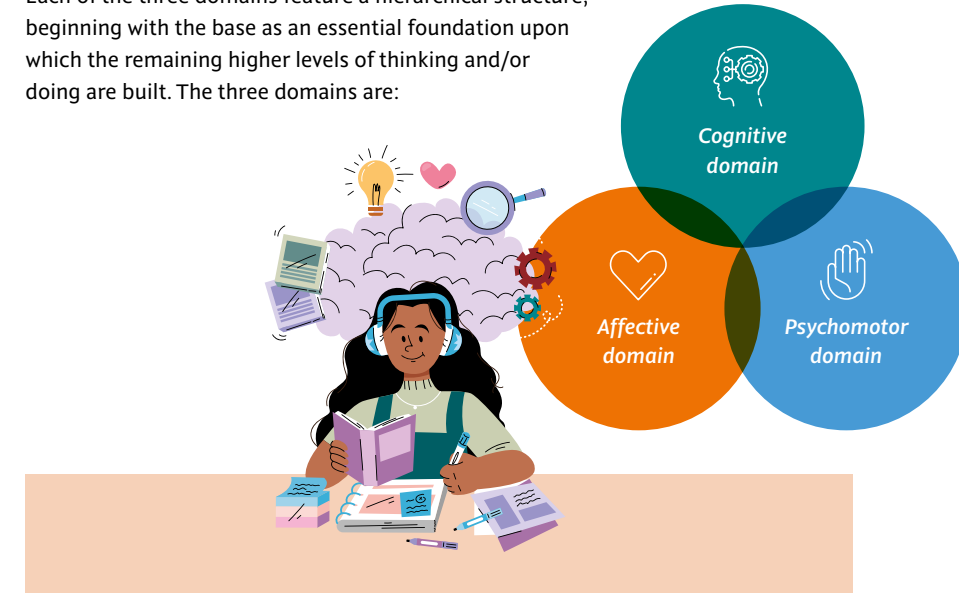


For example, at the elementary and high school levels, lessons can focus on basic geometry and forego the technical jargon for the types of symmetries. Students can simply identify how shapes are repeated by sliding (translation), turning (rotation), and flipping (reflection).

Next, by framing these geometric patterns in cultural or societal contexts in which they arise and highlighting their significance, this adds a deeper dimension to how Mathematics is grounded in culture and society.

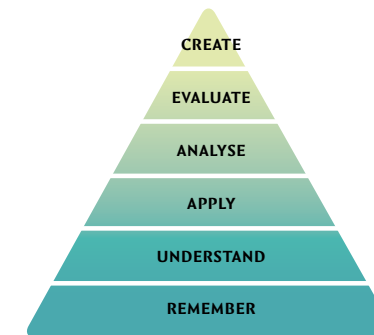
While not every mathematical topic lends itself to contextualisation, educators can thoughtfully select specific concepts that resonate with the local community and culture. These topics can be adapted across various grade levels and provide valuable opportunities for meaningful learning.

Each of the three domains feature a hierarchical structure, beginning with the base as an essential foundation upon which the remaining higher levels of thinking and/or doing are built. The three domains are:



1. Cognitive domain

The cognitive domain has been the primary focus in education and has become a shorthand for Bloom's taxonomy as a result.



- 6. **CREATE**
Create a new or original work
- 5. **EVALUATE**
Make judgements based on criteria and standards
- 4. **ANALYSE**
Break materials into components and determine how they work together
- 3. **APPLY**
Use a procedure in a given situation
- 2. **UNDERSTAND**
Determine the meaning of instructional messages
- 1. **REMEMBER**
Retrieve relevant knowledge from memory



SCAN TO READ
More about Bloom's taxonomy and its uses in creating learning objectives

1. <https://teaching.uic.edu/cate-teaching-guides/syllabus-course-design/blooms-taxonomy-of-educational-objectives/>

2. Affective domain

The affective domain² outlines skills and behaviours that correspond to attitudes and values. As the learner progresses through the levels of the affective domain, they become self-reliant and intrinsically motivated.

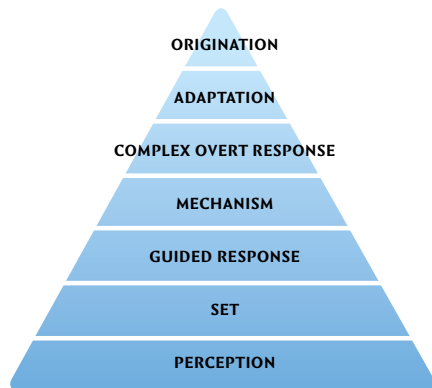


(Krathwohl et al., 1964)

5. **CHARACTERISING**
Creates a value system that controls behaviour. The behaviour is pervasive, consistent, predictable, and characteristic of the learner
4. **ORGANISING**
Integrates and compares values, resolves conflict between these values, and orders them according to priorities
3. **VALUING**
Finds value and worth in one's learning with motivation to continue
2. **RESPONDING**
Actively participates and engages in knowledge transfer
1. **RECEIVING**
Willing to listen and receive knowledge

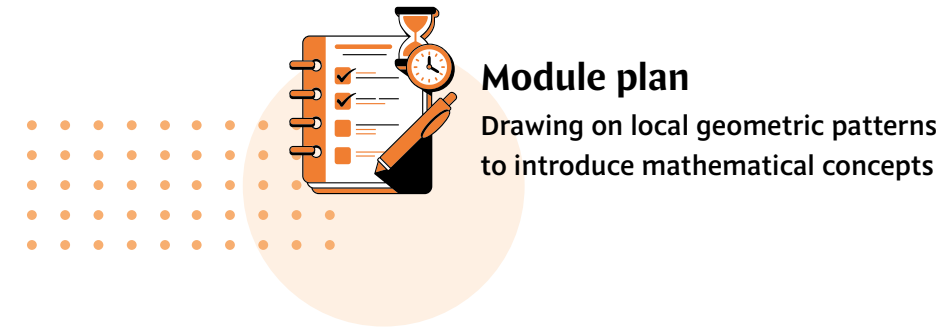
3. Psychomotor domain

Subcategories for skills in the psychomotor domain were created by other educators, supplementing Bloom's research. The psychomotor domain includes physical movement, coordination, and motor skills.








7. **ORIGINATION**
Creates new procedures and solutions to approach various situations
6. **ADAPTATION**
Performs tasks or objectives and can modify actions to account for new or problematic situations
5. **COMPLEX OVERT RESPONSE**
Performs tasks or objectives in a confident, proficient, and habitual manner. Expert level, high proficiency, and performs with accuracy
4. **MECHANISM**
Performs tasks or objectives in a somewhat confident, proficient, and habitual manner
3. **GUIDED RESPONSE**
Knows steps required to complete a task or objective and learns through trial and error, and practice
2. **SET**
Demonstrates readiness (physically, mentally, emotionally, and spiritually) to take action to perform a task or objective
1. **PERCEPTION**
Uses sensory cues to guide actions or movements

² Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals, Hand book II: Affective domain*. New York: David McKay Company Incorporated.



i. Desired learning outcomes

Desired learning outcomes	Rationale
 <ol style="list-style-type: none"> 1. Describe geometric patterns in everyday objects. 	<p>Students shift from remembering (retrieval and recognition) to understanding as they construct their descriptions based on their observations (cognitive domain). The activity also engages the affective domain as it is rooted in objects that are part of students' personal or community experiences.</p>
 <ol style="list-style-type: none"> 2. Identify types of symmetries in geometric patterns. 	<p>Students apply their knowledge by identifying the different types of symmetry and move upwards in the cognitive domain hierarchy of learning.</p>
 <ol style="list-style-type: none"> 3. Examine how cultural identity or discipline-specific context can be observed in geometric patterns. 	<p>The learning outcome ties in both cognitive and affective domains. Students examine and analyse (i.e., cognitive domain) the geometric patterns, and learn to value their cultural, disciplinary, or societal significance (i.e., affective domain).</p>
 <ol style="list-style-type: none"> 4. Create a geometric design inspired by personal or community experience. 	<p>Creation is usually classified as the highest level in the cognitive domain. However, for this learning outcome, the level of thinking is more akin to applying their knowledge.</p>
 <ol style="list-style-type: none"> 5. Relate geometric designs to cultural, disciplinary, or societal contexts. 	<p>Parts of the lessons require mathematical rigour, such as in the identification of symmetry type, frieze pattern, or wallpaper group. The rigour here involves mid-level analysis of geometric patterns. This is intended as a springboard for deeper introspection, engaging students in the fourth level of learning in the affective domain (i.e., to organise); here, students relate how mathematical concepts are used in culture and society.</p>

ii. Carrying out the module

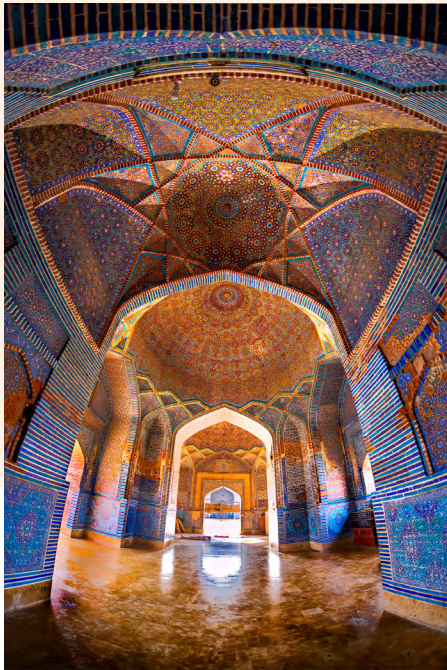
The topic was divided into four 1.5-hour lessons. For Dr Ariel, this equated to two classes each week over two weeks. This allowed students to have adequate time to concretise the knowledge learnt and complete the necessary preparations before each lesson.

ASSIGNMENT A

Discovering patterns in daily life

This assignment was given before lesson 1.

Students were tasked to bring everyday objects with geometric patterns that either represented local culture or had personal significance to them. The patterns could be drawn, printed, woven, or carved on the object, and could be linear, triangular, quadrilateral or hexagonal in nature. Some examples of objects brought were cloths, textiles, printed designs on paper or plastic objects, and photos of architectural designs.



Mosaic patterns in Shah Jahan mosque, Thatta, Pakistan

Students were then tasked to photograph repeating patterns found in manmade or naturally-occurring structures, such as in vegetation and geographic formations.

To emphasise the interdisciplinary and real-world relevance of Mathematics, students were shown examples of geometric patterns that are **rooted in culture** (such as in woven fabrics or carvings in historical sites), **discipline-specific** (such as in the design and structures of buildings), or **in the community** (patterns found in students' daily environment).



Woven patterns in indigenous Filipino tribe craft

Tips

- Rather than have students search for patterns on their own, consider a class field trip that showcases patterns within the community. Students can take photos of geometric patterns embedded within local architecture, public art installations, natural vegetation, or geographic formations.
- Some students may find it difficult to obtain a variety of objects that feature different types of geometric patterns. Students can be given the option of bringing prints of geometric patterns, such as the works of graphic artist M.C. Escher.
- Prepare several objects with different geometric patterns to serve as examples prior to the lesson.



Patterns found on animals and plants



Artwork of Dutch graphic artist M.C. Escher

Lesson 1
Bring along a
geometric pattern



a. Introduction (15 mins)

Dr Ariel began the lesson with the background of the activity, and what students could expect in the next four lessons.

b. Group activity (30 mins)

Students were then divided into groups of at least five students to compare and contrast the patterns in the objects or printouts they brought.

The groups identified common shapes and themes among the geometric patterns observed and discussed any cultural or local significance the patterns might have had.

During this activity, the teacher allowed students to use terminology that was familiar to them instead of enforcing mathematical jargon. The purpose of this initial activity was to ground the topic in personal experiences or relate it to their immediate community. Students built on their mathematical content knowledge in the subsequent lessons.



Spotting geometric patterns in everyday life

c. Presentations (30 mins)

Each group then presented the similarities and differences in the geometric patterns among the objects brought by their members. Around five minutes were allocated to each group to share their observations. Fellow classmates were also given the opportunity to provide comments.

Dr Ariel also pointed out common designs and themes among the objects, explaining how geometric patterns were formed through translation, mirror reflection, and the rotation of shapes that were triangular, rectangular, or hexagonal.

d. Wrap up (15 mins)

Students recapped the common themes or motifs identified as a class. In preparation for lesson 2, students learned that while the designs and usage of patterns might have differed, common patterns and geometric structures could be identified among them.

ASSIGNMENT B

Understanding mathematical symmetry

Given at the end of lesson 1, assignment B tasked students to browse reference materials or watch videos on mathematical symmetries and their cultural, disciplinary, or societal significance.

A list of suggested references was provided for their reference:



SCAN TO WATCH
"The Science of Symmetry"
by Colm Kelleher
(Ted-Ed video)



SCAN TO WATCH
"The Complex Geometry of
Islamic Design" by Eric Broug
(Ted-Ed video)



SCAN TO WATCH
"The Infinite Pattern that
Never Repeats"
(Veritasium video)



SCAN TO WATCH
"Glide Planes and Wallpaper
Groups" by Frank Hoffman
(Lecture)

Lesson 2
Symmetries in
geometric patterns

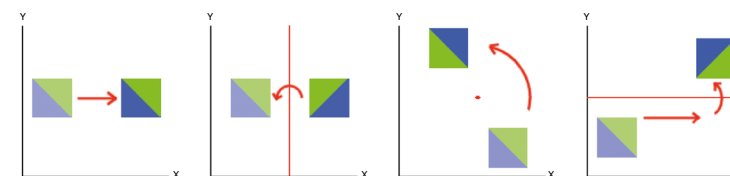


In this lesson, students identified the types of symmetries in the patterns on the objects or printouts from lesson 1.

a. Lecture-discussion (30 mins)

Here, Dr Ariel provided a brief exposition about the different symmetries found in geometric design.

Starting with diagrammatic examples of **translations**, **reflections**, and **rotations**, students were introduced to **rigid transformations** or **rigid motions** whereby a shape does not change in size and dimension.



Translations

Reflection

Rotation

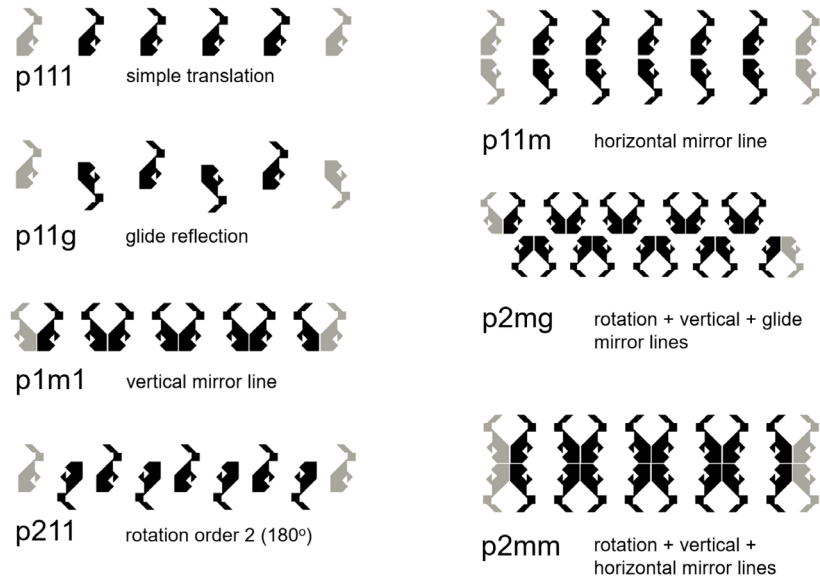
Glide reflection

2D rigid transformations

Different symmetries can hence be produced by combining these rigid transformations. In addition, printed or woven objects and geometric patterns can be one-dimensional (linear) or two-dimensional.

One-dimensional designs

A **frieze pattern** is a symmetrical design that is repeated along a one-dimensional band.



The seven frieze patterns

Two-dimensional designs

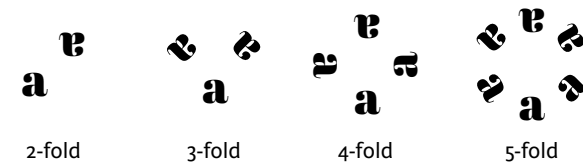
Two-dimensional patterns come in the form of **tilings** or **tessellations**. These are often seen in the design of tiles, wallpapers, and woven fabrics.



Two-dimensional patterns

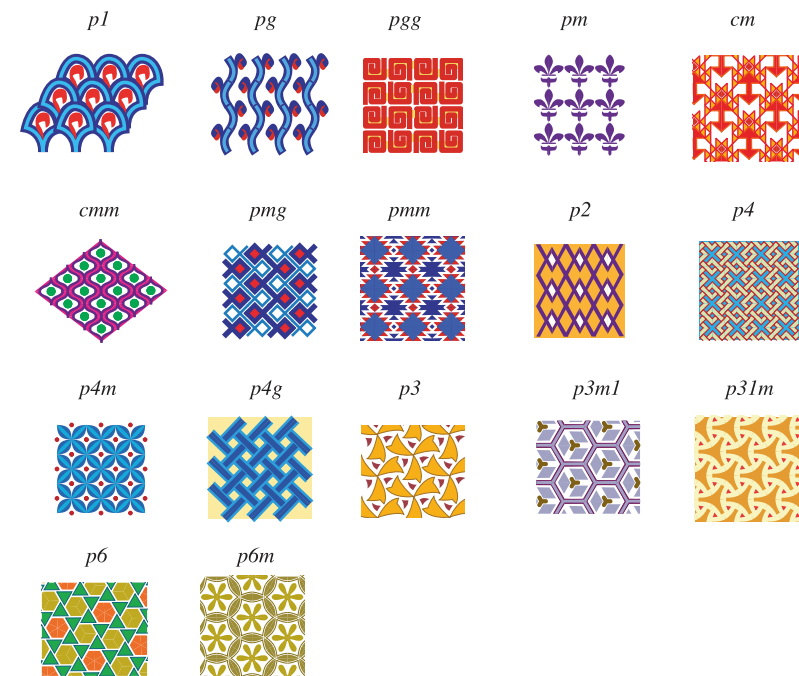
Regular tiling is formed by repeating a single shape from edge-to-edge so that multiple copies cover a surface. Irregular tiling uses several shapes that can be of different sizes to cover a surface.

The regular tilings or tessellations are called **wallpaper groups** or **two-dimensional crystallographic groups**. These tilings are combinations of translations, reflections, and rotations (two-fold, three-fold, four-fold, or six-fold).



Rotation patterns

Mathematically, it is proven that there are only 17 distinct regular tilings (wallpaper groups) of a plane based on these symmetries.



17 distinct wallpaper groups in regular tiling

While there are also three-dimensional crystallographic groups, this was not covered in-depth in this lesson.

Next, students learned that symmetries and wallpaper groups can also be found naturally around us and in manmade structures.

Naturally-occurring symmetries



Snowflakes



Fiddlehead fern



Dahlia flower



Giant's Causeway, Northern Ireland



beehive

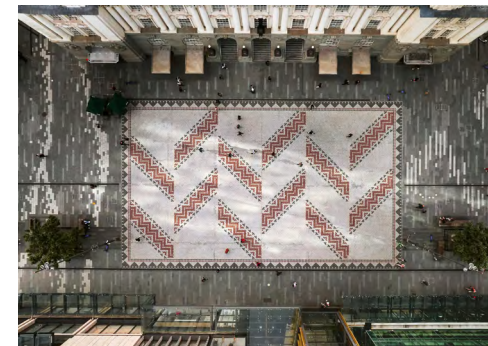
Man-made symmetries



Chhatrapati Shivaji International Airport, Mumbai



Glasgow University Cloisters



Te Komitanga, Auckland



Wallpaper

Tips

- As the first part of the lesson is an exposition of mathematical content, teachers may wish to incorporate the lecture material into Assignment B to free up time for the group activity.
- It is important to prepare a diverse range of geometric examples featured in different disciplines and contexts as an adequate variety may not be available within the immediate locality. This can be compiled as a slide presentation or as a set of printed visual aids that can be passed around during the class.

b. Group activity (30 mins)

For this activity, the class used the patterns from the previous lesson. Each group was tasked to identify the types of symmetries observed in the geometric patterns, and determine the **frieze pattern for the one-dimensional designs**, and **wallpaper group for the two-dimensional designs**.

Teachers may wish to assign a specific pattern to each group to maximise time and ensure that varied examples are covered.

c. Presentations (30 mins)

A representative from each group presented one example on how they identified the symmetries found in their pattern and the type of frieze pattern or wallpaper group observed. Students needed to provide their insights on the cultural, disciplinary, or societal significance of their pattern.

ASSIGNMENT C

Making your own geometric pattern

This activity was done in class, with the aim of getting students to build their own tessellation tile. Before class, students were asked to bring the following art materials:

- Paper
- Cardboard
- Colouring materials
- Sticky tape
- Safety scissors

The following instruction sheet and videos were shared with students in advance:



SCAN TO READ
Instruction sheet



SCAN TO ACCESS
Resources on how to create tessellations inspired by M.C. Escher



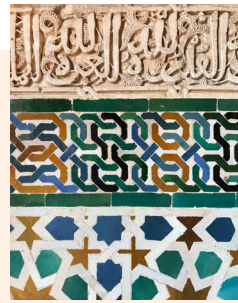
SCAN TO WATCH
Video on how to construct triangle-based tiles



SCAN TO WATCH
Video on how to create simple square tiles



SCAN TO WATCH
Video on how to create square tiles with 4-fold symmetry



Frieze patterns of the Alhambra, Spain

Students could bring materials of their choosing and were encouraged to share them with their classmates. Dr Ariel also prepared some pre-cut tiles for ease of demonstration.

Students were then tasked to design and make their own geometric tiles that they used to tessellate a sheet of paper. Teachers attempting this lesson can adapt any of the linked instruction sheets to their lesson needs. During class, the teacher can conduct a demonstration or play instructional videos that students can follow to scaffold the tessellation process.

Students were also encouraged to assist one another and discuss the construction process with their classmates. This allowed students to find support and provided Dr Ariel the chance to personally assist students who needed more guidance.



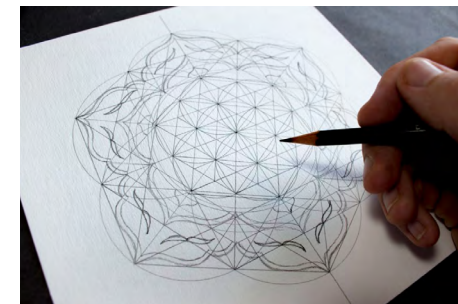
Tips

- If class time is limited, students can be tasked to watch the instructional videos in advance.
- The construction of tiles can also be done outside of class time as a pre-class assignment. This frees up more class time for students to explain the motivation and rationale behind their design choices.
- It is still recommended that the main activity of creating the artwork is conducted during class time to allow for collaboration as creating artworks with others is fun!



(top) Example of a reptile-shaped tile constructed by M.C. Escher, used in a tessellation puzzle
(bottom) Artist drawing an Asanoha Mandala

Lesson 3 Creating personalised geometric designs



a. Speaking with a resource person (30 mins)

Inviting one or more resource experts offers a glimpse into the sensemaking and meaning-making underlying the geometric patterns. This broadens students' perspectives and extends beyond what they have learnt in the classroom. A local artisan, artist, or arts teacher who works with geometric patterns can be invited to provide insights on the use of these symmetries in their craft; a historian or anthropology expert can briefly discuss the cultural or societal importance of geometric patterns; an architect or engineer can provide their expertise on how tiling and tessellations are used in manmade structures.

The expert can likewise be invited to supervise or observe the hands-on activity. For example, a local artist can provide guidance on how to find and tap on inspiration or motivation for designing their artwork.

In his class, Dr Ariel invited professors from the Arts and Humanities at UPLB to share their insights.



Tips

- Inviting a resource person from a non-Mathematics discipline is advisable here as it reinforces the cross-relational nature of Mathematics with other disciplines, alongside culture, society, and the immediate community.
- If the school calendar allows, a field trip outside of their immediate community to explore geometric patterns in their natural settings can further enhance students' appreciation of these patterns in a broader context.

b. Individual activity: Creating frieze patterns (20 mins)

Each student chose a figure or shape that had personal, cultural, or societal significance and created a one-dimensional geometric design based on a frieze pattern.

c. Individual activity: Creating wallpaper groups (40 mins)

The goal was for students to construct a geometric design and attribute meaning to the elements in their design.

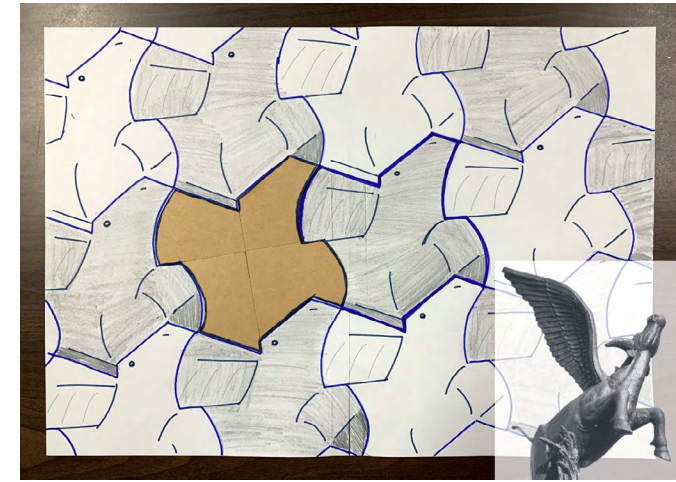
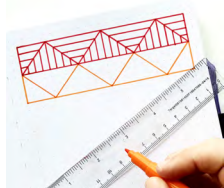
Prior to starting, Dr Ariel identified the shape of tiles the class was capable of constructing based on students' skills from previous lessons. He then shared instructional videos and guiding sheets to further support students' learning. The videos were played during class with careful pauses for students to follow and catch up. Instructional videos could also be shared with students in advance.

For this lesson, Dr Ariel prepared triangular or square tiles in advance, providing a foundational benchmark from which students could customise their design. Students had the flexibility to conceptualise their design before constructing their tile, or to construct an abstract composition before interpreting its meaning. Colouring materials were used for aesthetic and design personalisation purposes.

Students were tasked to first create three different tiles featuring a different symmetry on each tile before choosing one tile to create a tessellation design that filled a sheet of paper.

d. Wrap up

Students who did not manage to complete their task were asked to finish the artwork at home. Time was allocated for them to complete the finishing touches on their design in the last lesson.



Tessellation created by Dr Ariel using a tile in the image of a Pegasus: a monument of a hybrid mythical creature found on the UPLB campus



Tips

- The teacher should prepare the type(s) of tiles that will be used to construct the geometric patterns during class beforehand. Triangular or square-based tiles are easier to use than hexagonal tiles, as customising hexagonal tiles requires more steps.
- Prepare larger tiles as they enable students to better visualise the geometric properties of their designs and determine how they can manipulate and place their tiles.
- You may wish to run trials of the tessellation activity before the scheduled lesson to gain insights into potential challenges that students may encounter.
- For younger students, having them create one tile and one tessellation design might be sufficient within the class duration of 1.5 hours.



ASSIGNMENT D

Preparing to explain your artwork

Students were instructed to bring their artwork to the final class and prepare a brief narrative on its inspiration in the next lesson.

Lesson 4
Show and tell

To conclude this topic on geometric patterns in culture and society, the class had a show and tell session.

An arts teacher or a local expert can be invited to the show and tell to provide their perspectives on the artworks.

a. Presentations (60 mins)

Each student was tasked to present their artwork from the previous lesson. They were asked to provide the inspiration for their work, which could be personal, cultural, disciplinary, or community-focused.


Students were also asked to share what they learned in the lessons about the nature of geometry.

Feedback on their presentation and artwork was provided according to a marking rubric designed to address the intended learning outcomes of (1) understanding and applying symmetries, frieze patterns, or wallpaper groups, and (2) relating geometric designs to cultural, disciplinary, or societal contexts.

Category	Score			
	3	2	1	0
Use of geometric concepts (3 points)	The output shows clear and correct use of symmetries, frieze patterns, or wallpaper groups.	The output shows use of geometric patterns but is not clearly exhibited or incorrectly used.	The output shows minimal use of geometric patterns related to the topic	The output does not exhibit geometric patterns related to the topic.
Use of creative elements (2 points)		The output shows suitable use of color and artistic elements.	The output shows limited use of color and artistic elements	The output lacks creative elements.
Organization (2 points)		The output is organized with neatness.	The output lacks organization or neatness	The output is disorganized and lacks neatness.
Motivation for the design (3 points)	The student is able to clearly explain the personal or cultural motivation for the output.	The student provides the motivation, but it is not clear from the output.	The student's motivation is not clear from the explanation.	The student is not able to explain their motivation.
Composure and promptness (2 points)		The student was able to present with composure and promptly.	The student was able to present but lacks composure and promptness.	The student is not able to present at all.

Sample rubric for the art project on geometric patterns inspired by personal experiences and/or local culture

The rubric considered the following categories:

Category	Broader scoring consideration(s)
 Use of geometric concepts (3 points)	Application of STEM skills and the use of geometric concepts: <ul style="list-style-type: none"> • Logical thinking and an understanding of stepwise procedure are needed to follow instructions systematically in order to achieve the intended configurations. • Engineering design skills can be developed through the construction of their own tiles using simple construction tools. Students become more intentional through successive iterations of their tile designs.
 Use of creative elements (2 points)	Creative skills: <ul style="list-style-type: none"> • Imagination is needed to visualise what the final tile and tessellation would look like. • Artistic skills are developed as students apply their colour preferences to express personal style and creativity through the use of colour.
 Motivation for the design (3 points)	Content-related specialised skills and meaning-making: <ul style="list-style-type: none"> • Conceptual thinking is developed by providing the relevant contexts and exploring how and why geometric designs are used in real-world constructs. • Students are also encouraged to reflect on and articulate how the design relates to their own experiences.
 Organisation, composure, and promptness (2 points)	Soft skills: <ul style="list-style-type: none"> • Students develop organisational skills as they structure and prepare for their presentations. During presentation, students exercise openness to feedback and put into practice their presentation skills. Empathy and compassion are also exercised as students listen to and connect with their classmates' sharing.



b. Wrap up (30 mins)

To close this topic, the class discussed how their knowledge can be applied beyond the classroom.

Post-module activities: The artworks were exhibited in the classroom and around the school. It is possible to use these tiles to create designs that decorate other materials.



Samples of students' work displayed around the school

The class may explore further opportunities such as proposing a project for the whole school, or even the immediate community. They can also identify possible products that they can share as a fundraising activity for the school or community.

iii. Challenges and solutions in lesson implementation

Challenge	Potential solution
1. Limited lesson time	If limited time is available, the four lessons can be compressed into two lessons by combining lessons 1 and 2, and lessons 3 and 4. Rather than removing the involvement of a resource person entirely to reduce lesson time, consider retaining their participation in the feedback process in lesson 4.
2. Students may opt to use design elements that are not covered by the topics introduced	Given that the activity involves creative and artistic elements, students may lose sight and need to be reminded of the intended learning outcomes.



Author's reflections

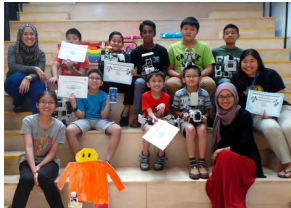
Mathematics is an abstract field of study; however, it need not be siloed to Mathematics classes. We can open the Mathematics classroom for discussions on culture, society, and the community. The key is to carefully plan how other disciplines are actively incorporated in the classroom activities rather than providing conceptual examples alone. This can include seeking experts from other professions or members within the community to be part of the classroom activities. Likewise, Mathematics can also be integrated into other subjects with which it is not traditionally associated.

To naturally incorporate cultural and societal contexts into Mathematics classes, consider (1) starting with students' personal experiences, (2) situating the Mathematics content in relation to what is already familiar to them, and (3) providing students with the topic's broader context.

Dr Ariel Babierra

Secret Agents: Learning Cryptography Through Ciphers

Mr David Chak



INSTITUTIONAL PROFILE

Arus Academy

LOCATION

Malaysia

TYPE OF INSTITUTION

Education social enterprise

LESSON DETAILS

NUMBER OF LESSONS

2 lessons

DURATION

60 mins/ lesson

GRADE LEVEL

Grade 9

SUBJECT/ DISCIPLINE

Basic Computer Science
(Asas Sains Komputer)

NO. OF STUDENTS/ PARTICIPANTS

30

STUDENT READINESS

Low readiness



Cryptography plays a key role in data protection in modern society. While its current applications in securing digital transactions, communications, and sensitive information are indispensable, its principles have roots that stretch deep into antiquity. Students may struggle with this topic without relatable experiences to ground its theories and keep them engaged. This lesson demonstrates how cryptography can be introduced to Grade 9 students in a low-resourced setting, imparting the fundamentals of cryptography through history and hands-on learning. Students experience creating their own Caesar cipher and actively practise simple encryption and decryption of messages, while being engaged in a mission as “secret agents”, making the lesson relatable, exciting, and memorable. This paves the way for deeper understanding of modern encryption technologies, with the hope that students organically develop an interest in cyber security.

In this chapter, we learn:

- ✓ The importance and mechanism of cryptography in computing and daily life
- ✓ How to encrypt plaintext and decrypt ciphertext using a key
- ✓ How to create and use a Caesar wheel for basic ciphers
- ✓ How to design a lesson using the Octalysis gamification framework

This lesson was designed as part of Malaysia’s National Education Form 3 Computer Science syllabus.

While Malaysian schools offering this subject are mandated to provide computers, this presents challenges such as students’ lack of prior (technical) knowledge, low student engagement through didactic approaches, and adequate teacher expertise. Given these challenges and the novelty and abstract nature of this unit, a more hands-on, gamified lesson delivered in a setting free of computers can be an effective way to establish a baseline understanding of cryptography.

Topics covered in this lesson

Form 3 Basic Computer Science
Unit 2.1: Cryptography in data security

- 2.1.1 Understanding the meaning and importance of cryptography in computing
- 2.1.2 Demonstrate ways to process ciphers that involves encryption and decryption
- 2.1.3 Produce and translate messages using cipher methods such as Caesar cipher

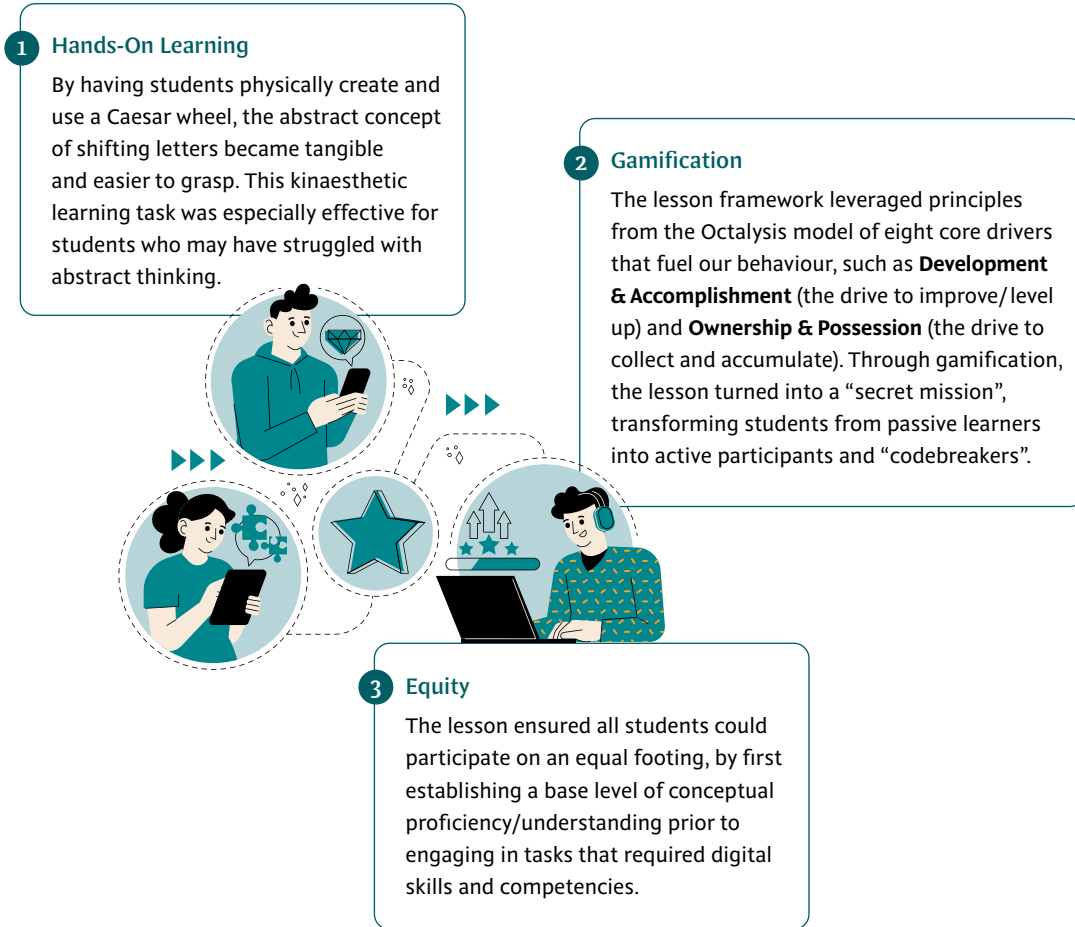
Learning cryptography in a low-resourced environment

This lesson tackled three primary challenges:

1. **Lack of Prior Knowledge:** It is common for students at this stage, irrespective of their background, to lack prior understanding of cryptography. While Computer Science is first introduced in Grade 4, cryptography is not part of the syllabus. This makes it difficult to introduce complex or abstract topics such as cryptography without establishing a foundational, relatable experience.
2. **Low Student Engagement:** Computer Science lessons often risk becoming “chalk and talk”, with teachers lecturing with the aid of a projector and students passively following teachers’ instruction on their computers. This approach can be dull, causing students to lose interest and disengage in the subject.
3. **Teacher Preparedness:** As Computer Science is a relatively new subject in the Malaysian curriculum, teachers may not be confident in their technical expertise to teach this lesson. Hence, the lesson design must support these teachers by providing a clear and easy-to-implement framework to ensure students achieve a baseline conceptual understanding before tackling more complex technical challenges.

To address these challenges, this lesson on the Caesar cipher was designed as an unplugged, hands-on, and highly gamified experience. The lesson plan was fun, engaging, and accessible to both students and teachers regardless of their prior knowledge and experience in cryptography.

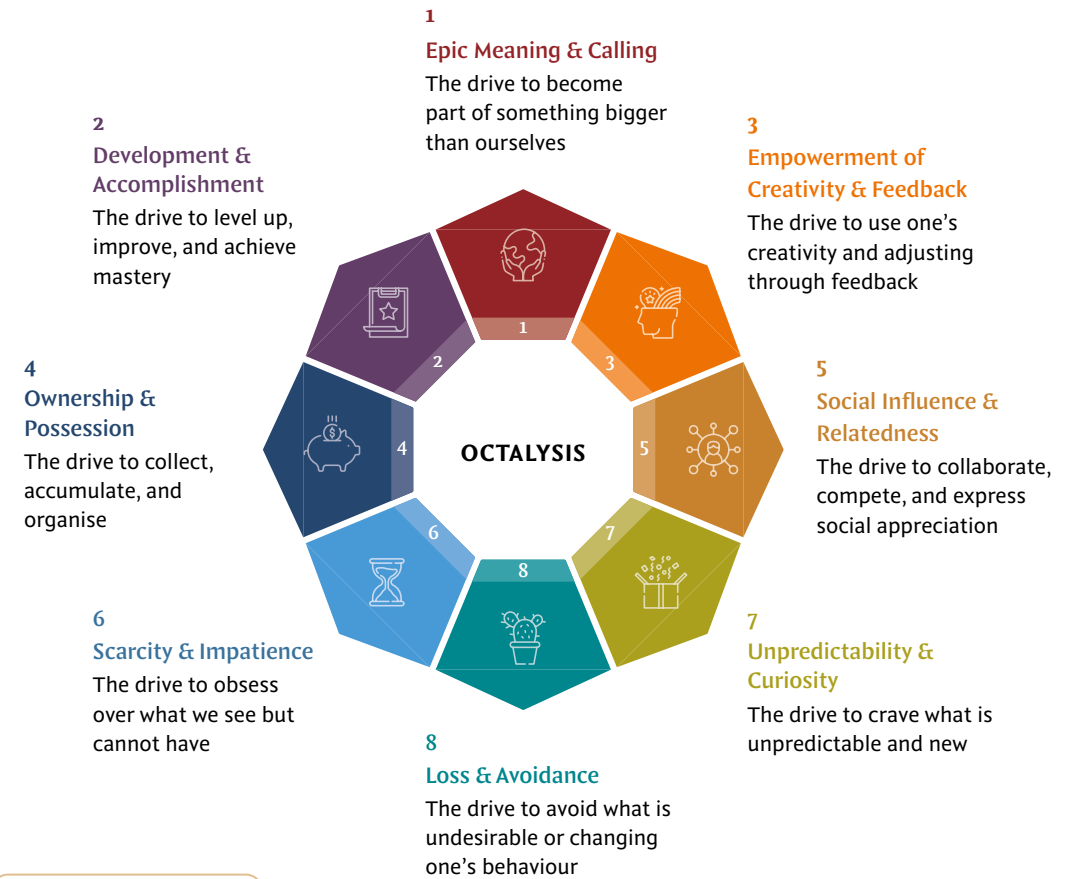
This approach was rooted in several key pedagogical considerations:



By making the lesson a fun and engaging experience, we can foster a positive perception of Computer Science and encourage students to become confident problem-solvers.

The Octalysis gamification framework

This lesson was designed in accordance with the Octalysis gamification framework by Yu-Kai Chou to create an engaging and motivating learning experience.



SCAN TO LEARN
More about the Octalysis gamification framework

The lesson exemplified the following principles:



- **Epic Meaning & Calling:** The lesson was framed as a “Secret Agent” mission. Students took on the role of new recruits in a top-secret agency whose mission was to “crack the code”. This elevated the lesson from a conventional activity to a collaborative mission and high stakes quest. It motivated students by giving them a greater purpose and a sense of being part of something bigger, making them more likely to invest time and effort.



- **Unpredictability & Curiosity:** The lesson centred on mysterious, sealed coded messages that students must decrypt. The unpredictable nature of the messages and the anticipation of what the final “secret message” will reveal, kept students curious and excited to continue with and see the mission through.



- **Development & Accomplishment:** The lesson plan was carefully scaffolded to provide a clear sense of progression, beginning with simple tasks, such as using a pre-determined shift key to encrypt a short phrase, to increasingly more difficult tasks, where students determined the key to longer messages themselves. As students successfully encrypted or decrypted a message, they gained a tangible sense of progress and mastery, which empowered them to take ownership of their learning process and tackle harder challenges.



- **Ownership & Possession:** This drive was addressed not only through the encryption/decryption process but also through students’ construction of their own Caesar cipher wheel. In addition, the act of creating and personalising the wheel helped establish a memorable conceptual anchor.



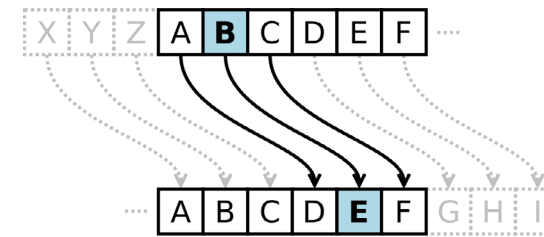
- **Social Influence & Relatedness:** Students worked in small groups as a “team of agents” to solve the messages, sharing in their successes, which built camaraderie and support. Competition was woven in as groups race to be the first to crack the final message, motivating them to collaborate with their team members and compete with their peers.



- **Empowerment of Creativity & Feedback:** One key activity in this lesson plan involved students writing their own secret messages to share with other groups. This allowed them to not only apply their new skills creatively to create something original, but also receive immediate and meaningful feedback on their understanding when their message was successfully decrypted by another group.

The Caesar cipher

The Caesar cipher is a simple encryption technique where each letter in a message is shifted a fixed number of places down the alphabet. The number of places shifted is called the “key” or “shift value”. Thus, with a key of three: A becomes D and B becomes E. This method of encryption was named after Julius Caesar, who used it to protect military communications.



Example of a Caesar cipher with a key of 3



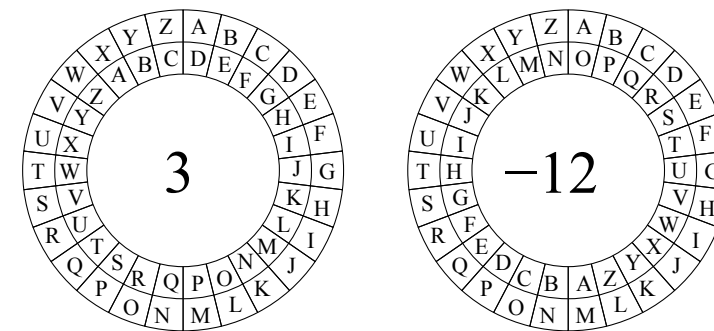
Roman messengers delivering coded messages during wartime



SCAN TO LEARN
More about the
Caesar cipher in
cryptography

Creating a Caesar wheel

Creating a Caesar wheel is easy for teachers and students to do, requiring basic materials such as paper, pencil, scissors, and a pin.



Examples of Caesar wheels with a key of 3 (left) and -12 (right)








SCAN TO LEARN
How to create
your own
Caesar wheel



Lesson plan

Learning cryptography through ciphers

i. Desired learning outcomes and objectives

Desired learning outcomes	Specific instructional objectives
 <p>1. Relate the meaning and importance of cryptography to computing</p>	 <p>1. Students will be able to explain the meaning and importance of cryptography in relation to computer science.</p>
 <p>2. Demonstrate ways to process ciphers for encryption and decryption</p>	 <p>2. Students will be able to perform both encryption and decryption using the Caesar cipher wheel as a tool.</p>
 <p>3. Produce and translate messages using cipher methods like the Caesar cipher</p>	



KEYWORD

Plaintext: The original message or data, before it is encrypted or encoded

Ciphertext: The message or data that is encrypted or encoded using a cipher

Key: The set of information needed to convert the plaintext into ciphertext, and vice versa

Encryption: The process of converting plaintext into ciphertext using a key

Decryption: The process of converting ciphertext back into plaintext using a key

ii. Carrying out the lesson

Lesson 1 The Secret Mission — Cracking the Code

This lesson introduced students to the core principles of encryption using the Caesar cipher, a foundational concept in cryptography. The entire lesson was framed as a “secret agent” mission to increase engagement and appeal to the learners’ sense of **epic meaning and calling**.

Materials required:

Each group (3–4 students) should have:

- **Envelope A:** Containing Caesar wheel cutouts and assembly instructions for each group member
- **Envelope B:** Containing a worksheet with simple sentences to be decrypted for each group member
- **Envelope C:** Containing the main encrypted messages for each group member to decrypt
- **Envelope D:** Containing messages for each group member to encrypt, an A4 sheet with the group’s name encrypted in a Caesar cipher, scissors, and paper fasteners for each group member

a. Secret agent induction (establishing the context) (10 mins)

Mr David began by greeting students and explaining they were “agents in training”. The encrypted group name, **Envelope A**, and **Envelope B** were placed on each group’s table. He then wrote an encrypted version of the school’s name on the whiteboard and shared that the same code is used to encrypt their group’s name. Mr David then led a classroom discussion on the importance of secrecy in communication, using modern examples such as texting friends to relate to students’ lived experiences.

He expanded the discussion to integrate the historical context of cryptography, explaining its critical use as a tool and weapon in conflicts like World War II and the Malayan Emergency, allowing forces to send and receive secret orders.

b. Introducing the Caesar cipher (20 mins)

He introduced Julius Caesar and the Caesar cipher using the whiteboard to visually demonstrate a simple encryption and define terms such as **plaintext**, **ciphertext**, and **key**. He then demonstrated how the cipher can be used to decrypt the school’s name on the whiteboard. Following the demonstration, students used the cipher provided to decrypt their group’s name before cutting and assembling their Caesar wheel using the instructions provided.

Lesson 2
The Final Mission
(game)

c. Guided practice (10 mins)

Students used their Caesar wheels to complete the worksheet from **Envelope B**. During this time, Mr David moved around the room, providing individual or group guidance as needed to ensure students were using the wheels correctly.

d. Independent practice (25 mins)

Next, students worked independently in their groups to apply their ciphering skills by decrypting the messages in **Envelope C** and **encrypting** the messages in **Envelope D**.

e. Closing (5 mins)

Mr David consolidated the lesson by recapping the importance of encryption and shared its use in the modern computing world.

This lesson focused on applying the skills from the first lesson through a high-engagement, competitive game.

Materials required:

Each group (3–4 students) should have:

- Two empty envelopes
- Blank A4 paper on the table
- Pens or markers

a. Final mission induction (10 mins)

After a brief recap on the Caesar cipher, students were reminded of their role as “agents” and were given their final mission. Each team had to select and hide their (1) “secret informant” and (2) location in the form of encrypted messages, while trying to retrieve and decrypt the location and information on another team’s “secret informant”.

b. Carrying out the mission (Game) (45 mins)

Final mission:

- Each team was instructed to come up with a list of 10 random words to represent their “informant’s” key information and encrypt them using a chosen key.
- A designated person from each team then hid the envelope containing the 10 encrypted words (**Envelope A**) somewhere in the school.

- The remaining team members created and encrypted a new list of 10 words describing the hiding location and placed this message in another envelope (**Envelope B**).
- Once everyone returned, teams exchanged their Envelope B with another team.
- Teams then decrypted the messages in Envelope B and went out in search of Envelope A. Upon finding the other team’s Envelope A, they then decrypted the messages to identify the traits of the informant. Teams were not required to guess the identity of the informant.
- The teacher’s role was to facilitate the game, ensure teams followed the rules, and verify the answers once a team identified the traits of the other team’s “secret informant”.



Tips

- Allow plenty of time for the activity by including some buffer time.
- Encourage students to come up with words of varying lengths to make the activity more engaging.

c. Closing (5 mins)

To conclude the final lesson, Mr David revealed the answers and led a debriefing session on the challenges of encrypting and decrypting messages in real-world contexts.

Encryption of credit card information

Mr David shared a real-world application of how encryption is used in securing credit card details for online shopping.

When shoppers input their credit card details into an online store’s platform, the browser uses the store’s public key to scramble the credit card number, turning it into ciphertext. This ciphertext then travels through the internet to reach the store’s server. If a hacker intercepts the data, the shoppers’ financial information remains safe as they will only get the ciphertext. Only the store’s server, which holds the unique private key, can decrypt the ciphertext back into the actual credit card number.



iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
<p>1. Teacher's explanation and demonstration ability in lesson 1</p> <p>This lesson places a significant emphasis on the teacher's ability to explain and demonstrate concepts fluently without over-referencing source material. The success of the "secret agent induction (establishing the context)" and "introducing the Caesar cipher" relies heavily on the teacher's verbal communication skills and ability to use the whiteboard effectively. This is particularly relevant for non-technical teachers who may not be as comfortable with abstract computer science topics.</p>	<p>Provide a clear, well-rehearsed script with specific talking points, simple analogies, and a step-by-step visual guide for the whiteboard demonstration.</p> <p>Teachers should practise communicating and explaining technical terms effectively before the class and anticipate and prepare responses to questions students may pose.</p>
<p>2. Group work management</p> <p>Effective group work is crucial in both lessons. The challenges here involve students working independently and as a team. If students are not accustomed to collaborative tasks, this can lead to some members dominating the tasks, while others remain passive.</p>	<p>Clear ground rules and norms for group work should be established and reviewed before each activity. This includes roles for each group member (e.g., leader, note-taker, cipher-runner) to ensure every student is actively involved.</p>
<p>3. Logistics in lesson 2</p> <p>The second lesson presents two unique logistical challenges. The first is ensuring students generate appropriate words for their encrypted messages. Without teacher supervision, this could lead to the use of offensive or inappropriate language. The second challenge is managing the students' movement outside the classroom. The game's highly active nature could lead to over-stimulation, making it difficult for students to focus on the core encryption and decryption tasks once they return to the classroom.</p>	<p>These challenges can be addressed by setting strict ground rules beforehand, including clear expectations for behaviour, appropriate word choices, and a well-defined time limit for each phase of the game to maintain a consistent pace and smoother transition between phases.</p>



Author's reflections

This lesson centres on cryptography and its principles as a fundamental aspect of modern life, encompassing tasks such as secure financial transactions to personal communication.

Students may carry the misconception that cryptography is a new, complex technological invention, yet its roots stretch back to antiquity. At its core is a timeless and simple mechanism: given a readable plaintext and a specific key, one can encrypt the plaintext into unreadable ciphertext; the same key can also be utilised to decrypt the ciphertext back into the original plaintext.

This lesson thus serves as an ideal and engaging entry point for Grade 9 students, especially for those with an interest in digital security, which is a vital and niche area in Computer Science. Regrettably, educational discussions on Computer Science often leave out the importance of cybersecurity though it is an equally critical component of our digital infrastructure. My ultimate wish is that this foundational lesson sparks a genuine and enduring interest in cryptography.

As technology continues to advance exponentially, the global demand for sophisticated and talented cybersecurity personnel increases in parallel. By making this field accessible and relevant now, I hope that this experience will encourage some students to become the next generation of security experts dedicated to protecting our collective digital future.

Mr David Chak

Modelling STEM Solutions to Reduce Inequality

Ms Yunyoung Jeong



INSTITUTIONAL PROFILE

Haesung Girls' High School

LOCATION

Seoul, South Korea

TYPE OF INSTITUTION

Private high school

LESSON DETAILS

NUMBER OF LESSONS

5 lessons

DURATION

120 mins/ lesson

GRADE LEVEL

Grade 12

SUBJECT/ DISCIPLINE

Humanities and Social Sciences

NO. OF STUDENTS/ PARTICIPANTS

25

STUDENT READINESS

Mixed to high ability

Addressing social inequality can be a complex task, but a necessary one should we wish for a sustainable and just society. This lesson presents a unique module that unpacks social inequalities in South Korea from a statistical lens, guiding students through a multi-phase design thinking process that has them refine a social issue and iterate actionable solutions to address its structural causes. The module, taught to students in the humanities track, demonstrates how STEM subjects can be integrated into civics education, while informing practical solutions for social change. This example follows one student group's project in addressing **climate inequality in an ageing society**.

In this chapter, we learn:

- ✓ How to use design thinking to structure a module on addressing social inequality
- ✓ Key causes of structural inequality in South Korea, and the vulnerability of the elderly to climate-related disasters
- ✓ How to incorporate statistical analysis to substantiate claims and inform solution ideation
- ✓ How to use the Futures Wheel for solutions modelling
- ✓ How to facilitate an iterative process of deriving solutions, and manage a class with diverse topics and proposals

Society today faces a wide spectrum of inequality — ranging from the climate crisis, poverty, and gender discrimination to unequal access to education and xenophobia. In South Korea, structural inequalities such as eldercare disparities, real estate wealth gaps, and youth unemployment are becoming increasingly severe. While these issues may seem unrelated, they are often deeply rooted in institutional and systemic structures.

This lesson was taught to students in the humanities track, as a follow-up project based on a Grade 12 semester-long Modern Literature Appreciation unit within the South Korean Language curriculum.

Education must be transformative and bring shared values to life. It must cultivate an active care for the world and for those with whom we share it.

*Former UN Secretary-General
Ban Ki-Moon*



In the South Korean national curriculum, the “One Book per Semester” reading programme is a required component, and this unit leveraged the dedicated time for in-depth reading and literary engagement. Through discussion and critical reflection on the stories and characters in the novels, students explored the realities of social inequality and the lives of marginalised individuals.

This module built on these literary experiences by encouraging students to take their critical reflections further, and connect what they read to real-world problems. As the goal was to move from awareness to action, students analysed social inequality through the lens of social justice, civic responsibility and interdisciplinary thinking. They made use of real-world data, policy analysis, and design thinking to propose practical, evidence-based, meaningful solutions to these issues.

Given that students were given autonomy over the issue(s) and solutions they designed, this gave space for creativity and the development of a variety of solutions. Some examples of student-designed solutions to address the structural inequalities included:

	Locally-tailored climate adaptation policies to protect ageing populations vulnerable to heatwaves and climate-related disasters
	Digital accessibility support and education programmes for socially vulnerable groups without access to public services, due to gaps in digital literacy and access to digital devices
	Policy interventions to reduce wage gaps and precarious working conditions faced by female workers, including improvements to working environments, caregiving support, and career development initiatives
	Developing apps to help consumers identify greenwashing in the fashion industry
	Identifying equity gaps faced by children from low-income households affected by climate vulnerability, and proposing inclusive service delivery models through a public participation platform
	Developing a simulation app that mirrors common kiosk interfaces that senior citizens struggle with for practice, paired with hands-on kiosk training in community spaces such as senior centres

In addition, students also put forward participatory budgeting models to encourage civic participation, and fund public awareness campaigns to bring the voices of marginalised groups into public discourse.

This experience enabled students to reflect on their role in society and ways in which they could become active, responsible citizens capable of addressing inequality with informed and meaningful action.

Topics covered in this lesson

Discovering key causes of inequality

- Unequal access to quality education due to geographic, economic, or cultural barriers
- Gaps in legal protection and representation for marginalised communities
- Limited access to public services (healthcare, welfare, transportation) in underprivileged areas
- Policy blind spots that fail to address structural inequality
- Lack of inclusive administrative systems that reflect diverse social needs

Examples of student-selected domain-specific topics

Social inequality, digital inclusion, & civic awareness

Examples included: the digital divide (connectivity and access to infrastructure), digital literacy, ageism, social isolation, information accessibility, etc.

Education policy & access

Examples included: the rural and urban educational divide, resource equity (e.g., teacher distribution, funding), adaptive learning (e.g., inclusion of educational technology)

Data science & civic technology

Examples included: systemic inequalities (e.g., school funding, arrest rates, healthcare outcomes), open data policy (government transparency), inclusive design, social forecasting, etc.

Urban planning & social infrastructure

Examples included: universal design and inclusive urbanism (e.g., human-centric planning, barrier-free design), inclusive mobility, and housing systems (e.g., transit-oriented development)

Public administration & governance

Examples included: the equity impact of social programmes (e.g., housing support, universal pre-school), inclusive service delivery models (e.g., participator budgeting platforms), etc.

Legal frameworks & justice systems

Examples included: institutional legal access gaps affecting public defenders and civil rights practitioners, secure digital systems and infrastructure for legal research and casework, citizen legal literacy, etc.

This project-based lesson helped students critically examine one or more aspects of social inequality and design data-driven STEM solutions related to their fields of interest.

The key questions driving this project were:



1. *How can students explore and propose solutions to social inequality issues related to their future careers?*



2. *How can STEM-based interdisciplinary thinking contribute to solving inequality in their communities or society at large?*

Design Process

The “Modelling STEM Solutions to Reduce Inequality” project followed a five-step design process developed by the ENACT Project team, led by Professor Hyunju Lee of the Department of Science Education at Ewha Womans University. Students formed teams based on their intended majors or career field of interest (e.g., law, education, public policy, data science, engineering and healthcare), and each team investigated a domain-specific structural inequality issue.

Key features in the design of this STEM-based project included:

- Social Issue Exploration:** Students defined key issues through literary texts, news media, and social discourse.
- Stakeholder Mapping:** Students applied sociological thinking to identify and analyse the structures surrounding inequality.
- Quantitative Modelling:** Students used real-world data to analyse the current state of the issue(s) being explored and forecast future outcomes if no intervention takes place.
- Policy & Design Thinking:** Students applied the principles of design thinking to develop realistic policy or programme models for their relevant sectors (e.g., education, welfare, and law).
- Implementation & Action:** Students outlined a practical actionable plan and, if feasible, designed a community-based implementation strategy.

By engaging in the full design thinking process — from problem definition to data analysis, solution conceptualisation, design, and planning for real-world implementation — students moved beyond theoretical understanding to develop empathy, civic awareness, critical thinking, and creative problem-solving skills.

KEYWORD

Sociological thinking, or the sociological imagination, refers to a way of viewing the world through considering social structures, human behaviour and group dynamics. The basic insight of sociology is that human behaviour is shaped by the groups to which people belong and by the social interaction that takes place within those groups.

SCAN TO LEARN

More about the sociological imagination



Lesson resources

This module references both teaching slides and a slide deck of students' sample works.



The lesson design slide deck



A sample group's work



Module plan

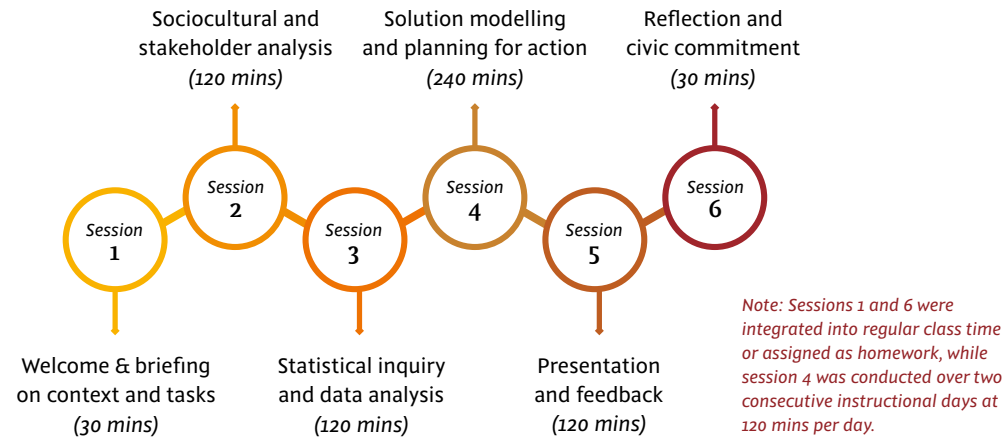
Modelling STEM solutions to reduce inequality

i. Desired learning outcomes and objectives

Desired learning outcomes	Rationale
1. Problem-based learning	<ul style="list-style-type: none"> Students identify and define authentic social issues of their own choosing Students analyse the complexities of the issue(s) and how these affect various groups, systems, and environments by constructing stakeholder maps and forecasting future consequences (future wheels)
2. Inquiry-based learning	<ul style="list-style-type: none"> Students define a problem of their choosing and investigate the problem by critically examining existing data and solutions from multiple perspectives Students use qualitative and quantitative data to inform the design of their policy or programme model Students assess the feasibility of their model by considering its social, economic, and technological dimensions, and refine their solution(s) through iterative feedback
3. Critical reflection and social responsibility	<ul style="list-style-type: none"> Students critically explore social issues by evaluating information from various sources (information literacy) on inequality and develop a structural understanding of the problem Students propose actionable solutions and reflect on their broader social and ethical impact, moving beyond technical remediation to develop responsible, thoughtful approaches to complex issues Students develop implementation plans for their solutions based on community needs, cultivating a sense of global citizenship and social responsibility as they reflect on the meaning of civic action and their evolving role in society
4. Collaborative learning	<ul style="list-style-type: none"> Students share ideas, negotiate decisions, and build their collaborative and communication skills through teamwork

ii. Carrying out the module

The module took place over five instructional days, comprising five 120-minute lessons. It was implemented during flexible curriculum time following the end-of-term examinations. The lessons were structured as follows:



The lesson design adapted the non-linear, iterative approach of the design thinking process. While the table below seemingly shows a linear progression of the activities, students moved back and forth between the various stages when engaging in each activity. The mapping below is a simplified summary that demonstrates the overall alignment of the activities with the key stages in the project.

Design thinking stage(s)	Activity no.	Task
Empathise & Define	Activity 1	<ul style="list-style-type: none"> Understanding the theme of social inequality Problem identification and selection
	Activity 2	<ul style="list-style-type: none"> Applying stakeholder mapping and prediction tools to explore the projected structural and societal impact of the problem
Ideate	Activity 3	<ul style="list-style-type: none"> Ideating potential solutions based on statistical inquiry and data analysis
Prototype Design & Refinement	Activity 4 & 5	<ul style="list-style-type: none"> Solution modelling and planning for action using digital platforms and visual or physical mock-ups Presentation and feedback
	Activity 6	<ul style="list-style-type: none"> Reflection and discussion on civic responsibility and commitment Solution modification and/or planning for ongoing community action

Prior knowledge

This module focused on applying previously learned concepts rather than introducing new theory. As such, the topics below were covered in previous lessons:



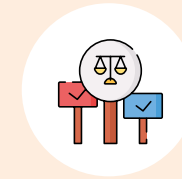
Definitions and types of inequality



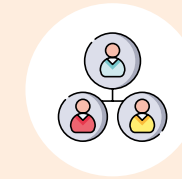
Real-world examples of discrimination against marginalised groups



Overview and significance of various social welfare systems



The concept of and controversy surrounding affirmative action



Polarisation and social stratification



Conditions and pathways towards achieving justice and reducing inequality



Probability and basic statistics
 (e.g., organising and classifying data, selection and interpretation of appropriate graph types for comparison/trend analysis)*

**Knowledge on concepts such as normal distribution were not required*

These topics provided students with the conceptual tools to analyse and critique real-world examples of inequality; foster understanding of both their symptoms and underlying causes; and encourage critical debate on controversial and authentic case studies with data-informed reasoning through statistical thinking and mathematical communication.

Grouping according to interest

A pre-lesson survey was conducted based on the books students had read and students were organised according to these interests.

Pre-lesson 1 activity

Students were provided with a pre-lesson worksheet. The worksheet included different definitions of justice and questions that prompted students to draw on inequality-related issues identified in the literary texts students had read and shortlist potential topics of interest for class discussion and refinement. The worksheet's purpose was to encourage students to reflect deeply on these issues prior to the project-based lessons.

Activity 1
Welcome briefing
on context and tasks
(30 mins)

Materials used:

- Presentation slides or whiteboard
- Projector or screen
- Programme overview handouts
- Selected picture books, literary texts, and resources related to inequality

a. Introduction

Ms Yunyoung introduced the central theme of social inequality and its relevance to both local and global contexts. She explained the interdisciplinary nature of the programme, which integrates literature, sociology, data analysis, and policy modelling; and provided a roadmap of the six-session learning process and the expected deliverables. She also clarified group expectations, timelines, and assessment criteria.

b. Background reading

Students were guided through a combination of curated materials and structured prompts, providing a springboard to develop their understanding of and empathy for the structural nature of inequality.

News articles, films, and television dramas addressing social inequality in Korean society were viewed and discussed collectively in class. Students also revisited the pre-lesson worksheet. Together, these activities helped students narrow down and articulate a specific issue of interest in their groups.



SCAN TO WATCH

An example of a video shown to students, "Squid Game Reflects Korea's Inequality"



SCAN TO READ

A sample article sourced by students, "The climate crisis is more severe for the elderly and vulnerable"

c. Topic selection

Students selected from issues such as income disparity among the elderly, digital exclusion, gender wage gaps, and more. Topic selection was scaffolded through a combination of in-class guidance and preparatory work.

In this chapter, we follow one student group's project addressing "Climate Inequality in an Ageing Society". The students in this group shared the aspiration of majoring in social welfare or public administration.

STEP 1 Issue identification

Among the various social issues discussed in your group, choose one issue you are most interested in and explore its main points.

- Issues of Interest
Climate Inequality in an Aging Society



- What aspects of the issue are controversial, and why?

According to national and international research, older adults have been identified as one of the most vulnerable populations to the impacts of the climate crisis, including heatwaves, deteriorating air quality, and extreme weather events. Factors such as chronic health conditions, limited mobility, and unequal access to information reduce older adults' capacity for climate adaptation, and the continued growth of aging populations is expected to further increase the scale of these impacts and the associated social burden.

Among the various social issues discussed in your group, choose one issue you are most interested in and explore its main points(e.g. links to online news articles, reference books, etc.).

- Articles on Climate Vulnerability of Older Adults and Climate Complaints (Environment Daily) 7/JUL/2024
<https://www.hkbs.co.kr/news/articleView.html?idxno=763386>



- In Korea, a climate complaint has been filed, arguing that inadequate climate action violates older adults' rights to life and health, highlighting the climate crisis as a current human rights issue.
- Heatwaves are the most serious climate risk for older adults due to reduced temperature regulation, increasing the risk of heat-related illness, especially for those living alone or without cooling.
- Older adults are also vulnerable to floods and extreme weather, as evacuation and recovery are often difficult.
- Practical responses include heat alerts, accessible cooling centres, neighbourhood care networks, and targeted evacuation support.

Example of a stepwise guide for issue identification, with responses from a student group



Tips

- To gauge their readiness, present students with pre-assessments or short inquiry tasks to assess their prior knowledge before beginning the module
- To maintain student engagement, try providing a variety of resources such as media articles, short academic texts, and documentaries

Pedagogical considerations

- By allowing students to choose a topic of their interest, this may increase their agency and stimulate their intrinsic motivation to proactively engage in the inquiry process (self-directed exploration).
- Develop students' information literacy through the evaluation and verification of content from various sources.
- Use structured brainstorming, guided group discussion, and scaffolded instruction to facilitate student exploration, selection and conceptualisation of their personal stance on an issue of inequality (e.g., from concept → case study → analysis → personal stance).

Activity 2

Sociocultural and stakeholder analysis (120 mins)

Materials used:

- Internet-connected devices (laptops/tablets)
- Credible news articles, public reports, and NGO data
- Stakeholder mapping templates (paper or digital)
- Prediction tools (Futures Wheel)
- Coloured markers, strings, pins, or digital visualisation tools (e.g., Edrawmind, Jamboard)

a. Report analysis

Next, students examined the issue from sociological and structural perspectives by sourcing and analysing literary works and credible reports from a list of websites provided by Ms Yunyoung, to uncover the root causes of inequality.

Students also tapped prior knowledge gained from the “One Book per Semester” programme in their Modern Literature Appreciation module. In this module, students read from a list of curated books, and were guided to identify the underlying themes that related to the United Nations Sustainability Development Goals. This culminated in a final social critique report, which helped them identify existing social inequalities and recognise that the reduction of inequality is a key condition for building a sustainable society.

For this module, students used the information they gathered, to explain their position on their chosen issue, and why they selected it.

STEP 2

Issue Exploration

2-1. Briefly describe your opinion on the issue you selected.

- My position on the issue and the reasons for it

These cases clearly illustrate the serious impact of climate change on older adults in an ageing society. Extreme weather events and natural disasters pose significant risks to the health and safety of elderly populations, highlighting the unequal ways in which older adults are affected by the climate crisis.

In an ageing society, climate change should be recognized as a critical social issue. Older adults are particularly vulnerable to climate-related risks, and insufficient responses to extreme weather events can lead to severe health problems and safety threats.

Addressing this issue requires effective public policies and social services, including well-coordinated disaster response systems and age-friendly climate policies. To reduce climate-related inequalities, policy design must take into account the specific characteristics and needs of older populations.

Student group's reasoning for selection of the issue on “Climate Inequality in an Ageing Society”

b. Stakeholder mapping

Following this, students created stakeholder maps using visualisation tools such as mind maps and string maps, to map out key stakeholders in their chosen issue, analyse power dynamics and shared/differing interests, and illustrate the social forces influencing the issue.

KEYWORD

Stakeholders refer to individuals, groups, or systems that are directly or indirectly affected by a given issue or controversy. Their positions may differ depending on how the issue influences their interests, roles, or values. Stakeholders can include people or social groups, institutions, cultural systems, and natural environments (such as ecosystems, land, oceans, or the atmosphere), all of which may experience positive or negative impacts.

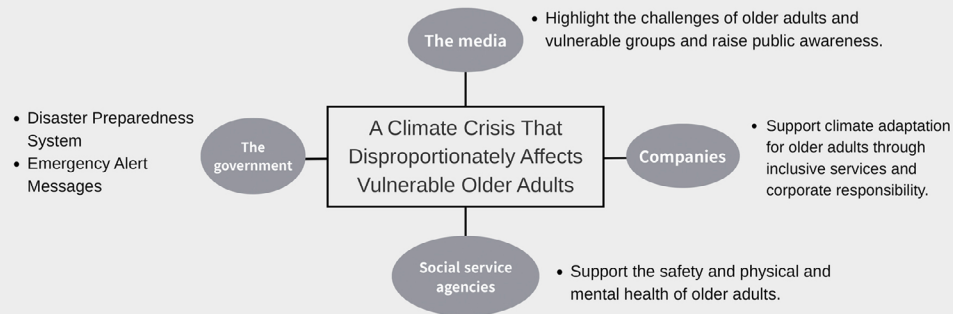


Student presenting their sociocultural and stakeholder analysis

Read another example of stakeholder mapping in chapter 4.3!

2-2. Create a stakeholder map that shows not only the people (individuals and groups) involved in the selected social issue, but also the direct and indirect impacts on the environment and culture.

- Write the social issue at the centre and identify the key stakeholders.



2-3. Based on your stakeholder map, identify the key stakeholders and explain why they are important.

Key stakeholders	Reasons
Central Government (e.g. Ministry of Environment; Ministry of Health and Welfare; Ministry of the Interior and Safety (National Disaster and Safety Control Headquarters))	
Companies	
Social Service Agencies	
Local residents and neighbours	
Family members	

Student group's reasoning for stakeholders of the issue

Pedagogical considerations

- Encourage students to broaden their perspectives and include in their research not just individuals and groups, but also environmental and cultural systems and stakeholders
- By using mapping and prediction tools, students develop systems thinking as the activity helps them shift the focus away from isolated events and visualise the connections between the structural and societal causes of inequality



Tip

Encourage students to explore and think more critically from multiple stakeholder perspectives through role play and/or debates

Activity 3
Statistical inquiry and data analysis
(120 mins)

Materials used:

- Public datasets (e.g., the Korean Statistical Information Service [KOSIS], government reports, NGO statistics)
- Spreadsheet software (Microsoft Excel or Google Sheets)
- Graphing tools (e.g., Canva, Desmos, Google Charts)
- Calculators, laptops/tablets

a. Sourcing for statistical data

In this activity, students gathered public datasets such as government reports and NGO statistics on the issue of their choice. They used a mix of hand-drawn graphs and tools like Microsoft Excel and Canva to visualise trends and disparities.

Figure 3-28: 서울시 고령가구 소득계층 분포(2012)

60세 이상 노인 및 독거노인 추이 (단위: 만명)

60세 이상 노인 및 독거노인 추이

최근 5년간 12월 초순 평균 일일 열사건 발생 현황

순영양분 밀도별 지명률(%)

The graph indicates that low-income rates are much higher among those aged 60 and over than among people in their 30s, showing a concentration of low-income individuals in older age groups.

This graph shows that the proportion of older adults living alone has been steadily increasing within the total elderly population.

The graph indicates that heatstroke deaths and heat-related illness cases are concentrated among older adults.

Graphical representations and students' interpretations of public data sets

Students predominantly used bar graphs to compare values across social groups or regions, and line graphs to examine patterns and changes over time.

b. Data analysis

Students used the graphs to (1) identify disparities between groups, such as differences in access to resources and health outcomes by region or socio-economic strata, and (2) evaluate temporal trends, noting fluctuations in key social inequality indicators like household income. This was followed by group and independent data interpretation.

Climate Inequality in an Ageing Society [TRENDS]

Factor	Trend	Implication/ Interpretation
Low income	> aged 60 and above compared to people in their 30s	↓ income in older age groups
Living alone	> proportion in elderly + steady increase in elderly population	↑ elderly living independently
Heartstroke-deaths and heat-related sickness	Concentrated among elderly	vulnerability of elderly to heat
Population in flood-/typhoon-affected areas	aged 65 and over = largest proportion	Elderly ↑ vulnerable to natural disasters

A student group's findings from data analysis

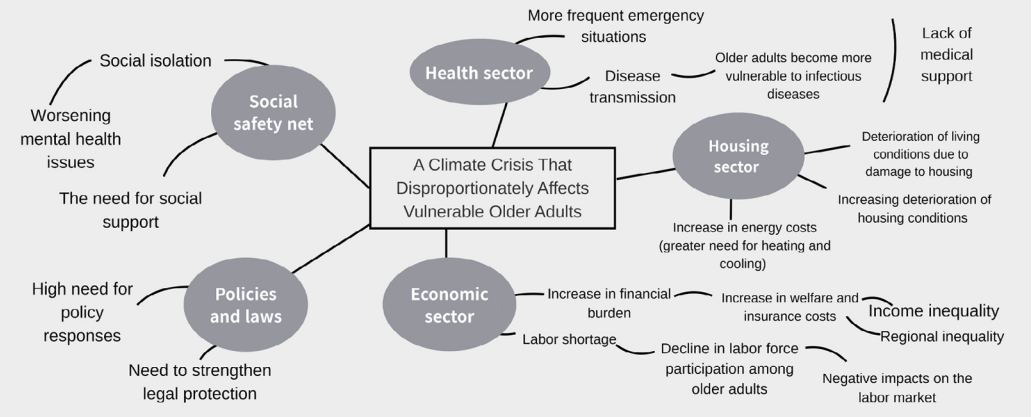
c. Future predictions using the Futures Wheel

To anticipate possible outcomes, Ms Yunyoung guided students in creating their own Futures Wheel for scenario modelling with the steps listed below.

- Write the issue or topic explored in Step 2 at the centre of the Futures Wheel
- Consider the first-order social impacts that may result from this issue across various domains, and record them around the central issue to form the first ring of the wheel
- Develop the second and third rings by identifying subsequent impacts, and continue expanding to include third- and fourth-order impacts where appropriate
- After expanding the wheel as fully as possible, use arrows to indicate causal or correlational relationships between social impacts that influence one another

STEP 3 Future Scenario Modelling

3-1. Use a Futures Wheel to identify and map the potential ripple effects (impacts) that may arise from the issue in the future.



An example of scenario modelling using the Futures Wheel

Students then had to answer two questions:

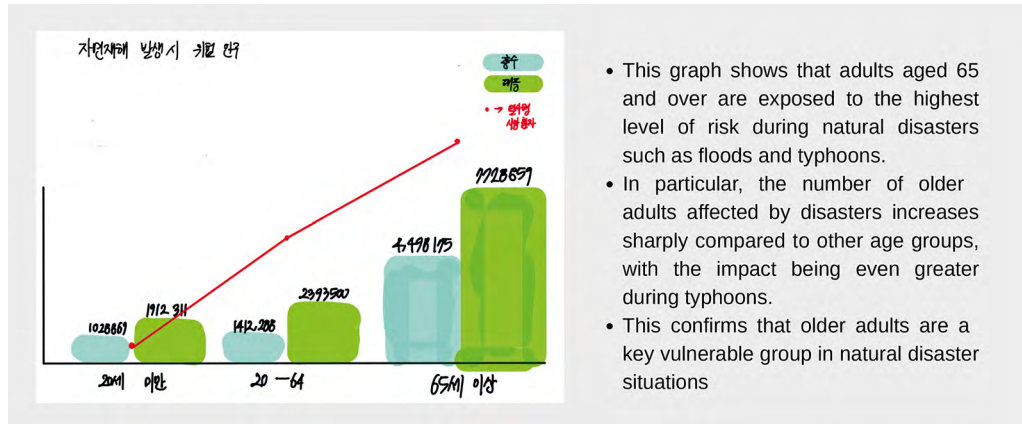
- Predict and describe what the future will look like in 10 years if the current problems continue without any effort to address them
- Predict and describe what society will look like in 10 years if the current issues are addressed and improved in a desirable way

Finally, students were asked to identify actionable solutions to move towards a desirable future outcome. To address climate inequality in elderly populations, students proposed developing:



d. Data reorganisation

In preparation for the final presentation, students were asked to reorganise their supporting data such that it would be engaging and translatable for a general audience.



- This graph shows that adults aged 65 and over are exposed to the highest level of risk during natural disasters such as floods and typhoons.
- In particular, the number of older adults affected by disasters increases sharply compared to other age groups, with the impact being even greater during typhoons.
- This confirms that older adults are a key vulnerable group in natural disaster situations

Example of a student group's interpretation of a graph

Given their reorganised data and knowledge gained from the Futures Wheel exercise, students predicted how the future was likely to unfold if nothing was done to resolve the issue. In this example, students noted:

1. There would be increasing health and survival risks for the elderly due to an increase in the frequency of climate disasters and heat-related health problems.
2. Social inequality will deepen as a result of concentration of vulnerable groups in the elderly population and limitations in existing support systems in reaching the vulnerable elderly populations.

Visit chapter 4.3 for another example of using the Futures Wheel for scenario modelling!



Pedagogical considerations

By analysing data patterns, students can deepen their understanding of the scope, causes and urgency of the issue examined.

Activity 4 Solution modelling & planning for action (240 mins)

Materials used:

- Planning templates (logic models, action canvases)
- Coding platforms (e.g., Scratch, MIT App Inventor, Thinkable)
- Prototyping materials (e.g., cardboard, clay, markers, sticky notes)
- Presentation tools (Google Slides, PowerPoint)

Based on their data analysis from the previous lesson, students designed practical interventions to combat inequality. These interventions ranged from policy proposals to digital tools and public service innovations.

Guiding criteria for practical interventions

Interventions were expected to be contextually grounded, feasible within real-world constraints, and clearly linked to the identified issue and stakeholder needs. Solutions must be data-informed and supported by existing policies, documents, and initiatives.

Emphasis was placed on relevance and social impact, rather than technological sophistication. Examples given of practical interventions included policy proposals, educational or public service initiatives, and simple digital tools or prototypes.

As the final stage of the project focused on taking action, interventions had to be implementable within the community.



a. Ideation and solutions proposition

Students were to brainstorm and present initial ideas to address the issue at hand. To address climate inequality in an ageing society, students proposed to:

1. Strengthen climate disaster preparedness and response legislation, and prioritise the protection of the elderly during climate disasters
2. Improve and protect housing environments of the elderly to withstand the effects of climate change
3. Enhance economic support and the social safety net through reforming pension systems and welfare policies

b. Intervention design for social action

Next, students put their plans into action and underwent multiple iterations of the solutions design process, following teacher and peer feedback at multiple points throughout the activity. While teacher feedback focused on feasibility and alignment of the solution to the issue, student feedback was given by peers within and between groups to encourage inclusivity and ensure solutions were clearly articulated.

Ms Yunyoung observed students informally exchanging ideas and seeking perspectives from other groups outside of designated project lesson time, indicating that peer interaction extended beyond structured class activities.

Iterative design process

Intra-group evaluation and review comprised a significant part of the solutions design process, where students discussed, reviewed, and negotiated their ideas within their own groups. These discussions played a central role in refining the proposed solutions and resolving differing viewpoints among group members.

Students typically went through a mid-point review followed by revision, and in many cases engaged in a second round of refinement. The process followed a review–revision–reconsideration cycle rather than a single revision, enabling students to refine their solutions based on key criteria such as feasibility, inclusivity and technological viability.



In this example, the students came up with the **Climate Adaptation Community Network Project** to tackle the issue of elderly populations being vulnerable to climate change.

The project had two components:

1. **The climate adaptation ambassador programme**, which involved high school students and local community members as Climate Adaptation Ambassadors. Following basic training, the ambassadors support the elderly in adapting to climate-related risks.

Anticipated outcomes were improved climate disaster preparedness and response capacity among the elderly, increased intergenerational ties, and enhanced civic awareness and social responsibility among students.

2. **Designing an elderly friendly climate adaptation information platform** for climate preparedness using low-cost, high-accessibility tools such as Google Sites, Notion, etc., to create an app or website.

Anticipated outcomes were improved access to community-specific climate-related information for the elderly, a reduced digital divide, and enhanced problem-solving skills for students.



As the lesson was designed to accommodate a variety of solutions, other teams used simple automation tools, platforms like Scratch and MIT App Inventor to prototype apps or websites, or visual or physical mock-ups to illustrate their ideas. Solutions were designed to embrace the students' interests and capabilities. For example, students that designed app-based solutions possessed prior knowledge on app development.

c. Active civic participation

As part of the project's call-to-action intention, students were encouraged to submit their finalised proposals to relevant Korean government agencies by posting them on official online public forums or proposal boards (e.g., the Ministry of Environment, Ministry of Economy and Finance, Ministry of Gender Equality and Family, and the Ministry of Education). This process provided students with an authentic experience of civic participation, reinforcing the idea that collective, small-scale actions can contribute to addressing structural inequality and social change. As submissions were intended for a real audience, this prompted students to refine their solutions with greater clarity and responsibility.

In one instance, a student proactively contacted a social affairs journalist through social media to share a proposal and seek external feedback, further emphasising that civic participation is an ongoing, iterative real-world practice.



e-People is an online portal for filing civil complaints or proposals to the government

Tips

- The lesson was intentionally designed to accommodate a wide range of solution types, given the diverse range of students' interests. Teachers can scaffold this diversity of solutions by applying shared evaluation criteria, encourage evidence-based justification of ideas, and allow multiple modes of expression and communication to maintain coherence and comparability across groups.
- Groups may experience conflicting opinions in the initial brainstorming process and require several iterative turns of ideation. As this extended negotiation is an important part of the learning process and reflects an authentic application of the design thinking framework, it may be helpful to consider including a time buffer in your lesson plan.

Pedagogical considerations

- Encourage students to tap on one another's prior knowledge and expertise to translate their practical solutions into tangible prototypes, such as an application or website
- Encourage students to think critically and reflect on real-world constraints such as budget and policy by providing guidance on assessing feasibility, scalability, and potential social impact of their solutions
- Effective visual communication is an important real-world competency; provide guidance to encourage students to use visual tools such as infographics, mock briefs, and diagrams to communicate their ideas

Activity 5 Presentation & feedback (120 mins)

Materials used:

- Projector or digital display
- Evaluation rubrics for peer and teacher feedback
- Printed or digital feedback forms

Groups were each given 15–20 mins to present their research, data findings, and proposed solution. Peer-led evaluation followed each presentation.

A peer evaluation rubric, which focused on formative aspects — such as the depth of understanding, creativity of ideas, and practical relevance of the proposed solutions — was designed and provided by the teacher to support constructive feedback. These evaluation sessions allowed students to reflect on one another’s work through structured discussion.

Teacher feedback was also provided to build on students’ observations, highlight key strengths, and suggest areas for further refinement.



Students presenting their research, data findings and proposed solutions

Pedagogical considerations

- To maintain consistency in students’ evaluation, provide clear instruction on how to use the rubric effectively
- Prioritise time for peer evaluation to encourage student agency and critical engagement; teacher feedback can be used to consolidate learning, ensure alignment with learning objectives, and guide subsequent reflection on future revisions

Final assessment criteria

1. Clarification of key issues

- Did the students clearly identify and define the issue with evidence of literary analysis and social inquiry?
- Was the issue critically analysed and meaningfully framed in a relevant social context?

2. Appropriateness of data use

- Did the students select and use accurate and relevant statistical or research data?
- Did the students purposefully connect the data to the learning goals?

3. Validity of data interpretation

- Was the interpretation of the data logical and supported by clear evidence?
- Were the conclusions well-grounded in data analysis?

4. Feasibility and execution of solutions

- Was the proposed idea or solution realistic and feasible?
- Did the students attempt to implement the solution (e.g., app development, policy proposal, campaign)?
- Was there a clear action plan for real-world application?

5. Competency in democratic citizenship & ecological awareness

(Based on South Korea’s 2022 Revised Curriculum)

- Did the students demonstrate understanding and respect for diverse perspectives and show responsibility as democratic citizens?
- Did the students show ecological awareness and a commitment to sustainable practices?
- Did the learning process reflect reflection, participation, and awareness of public values?

Activity 6 Reflection & civic commitment (30 mins)

Materials used:

- Reflection worksheets or digital journals
- Civic action checklist or follow-up plan templates

Students reflected on their learning process, challenges faced, and how their perspectives on inequality evolved. They discussed what it meant to be a socially responsible and active citizen, and brainstormed ideas for ongoing community action or personal commitments post-completion of this project.



Student voice

“I faced several challenges in this project. Finding reliable data and coordinating different opinions was not easy, and there were times I had to revise my plan due to unexpected problems. However, through this process, I came to realise that continuing to seek solutions instead of giving up is an important part of social responsibility.”

“Through this activity, I learned that social action to address the climate crisis and inequality faced by the elderly is more than just a school task. It is a responsibility that we should take on as global citizens. In the future, I hope to continue looking at social issues through a statistical lens and take action to create a better future.”



iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
<p>Difficulty in reaching group consensus on a central issue</p> <p>Some groups had trouble narrowing down and defining a central issue. Due to differing interests and perspectives among team members, conflicts arose in discussions, which delayed progress. Some students preferred topics that evoked empathy while others favoured more data- or policy-driven issues, making it difficult to align group expectations.</p>	<p>Provide structured worksheets to guide the discussion process. By incorporating timed activities and prompting questions — such as “Which issues do we personally find most important?”, “What evidence supports the urgency of this issue?”, and “Can this issue be realistically addressed with the data and resources currently available?” — teachers were able to guide students to think critically and efficiently about choosing a focus.</p>
<p>Difficulty in selecting a concrete topic</p> <p>Groups with limited background knowledge on social issues struggled to identify concrete topics related to social inequality. For instance, some chose overly broad issues like “poverty” or failed to select a topic at all. This lack of focus made it difficult for them to transition smoothly into the research or modelling phases and caused confusion with the project direction.</p>	<p>Introduce curated resources for students to read, including picture books, non-fiction excerpts, and news articles covering various types of inequality. Topics can range from refugee issues to gender wage gaps, racial discrimination, and labour conditions. This provides a broad knowledge base for students to work from while offering more targeted options for selection.</p>



Author’s reflections

This lesson design was grounded in an interdisciplinary approach, with Humanities and Social Sciences serving as the lead disciplines, guiding students to recognise the severity of their selected issues of inequality through the analysis of contemporary literature and empirical validation using data and statistical methods. To ensure equitable participation and responsible engagement in group work, the teacher provided ongoing and careful guidance; in particular, Ms Yunyoung employed the strategy of systematically reviewing individual activity sheets in each session. Overall, students perceived the learning experience as highly engaging and transformative, and recognised that issues of inequality are deeply rooted in the realities of contemporary society.

This STEM-based learning approach contributed to broadening students’ thinking throughout the project. Students proposed a range of context-responsive solutions — including the installation of public cooling benches; the development of kiosk guidance programmes for the elderly; and the design of applications to identify greenwashing in consumer products in response to support an ageing population against climate change. Through these activities, students not only engaged in forms of social action but also cultivated a sense of civic responsibility and experienced how learning can be meaningfully applied to address real-world social problems.

Lastly, some groups experienced difficulties in converging on a single shared focus. For example, even within the broad theme of gender inequality, students expressed divergent interests in subtopics such as educational inequality and labour inequality, reflecting their individual academic and career orientations. These contextual constraints suggest that incorporating an individual component that allows students to pursue their individual interests on a social inequality issue may be a meaningful and pedagogically appropriate alternative.

Ms Yunyoung Jeong

Combating Air Pollution in Lower Northern Thailand

Dr Artorn Nokkaew, Ms Suparat Chuechote, & Dr Thanyaluck Ingkavara



INSTITUTIONAL PROFILE

**Naresuan University
Demonstration School,
Faculty of Education,
Naresuan University**

LOCATION

Phitsanulok, Thailand

TYPE OF INSTITUTION

Public Secondary School

LESSON DETAILS

NUMBER OF LESSONS

1 lesson

DURATION

10 hours/lesson

GRADE LEVEL

Grades 8–12

SUBJECT/ DISCIPLINE

STEM club (extracurricular activity)

NO. OF STUDENTS/ PARTICIPANTS

11 (2–3 students per group)

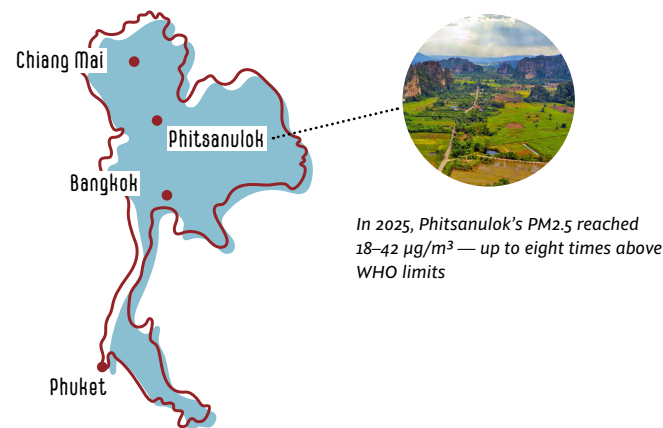
STUDENT READINESS

Mixed ability

Seasonal air pollution in Northern Thailand has been an increasingly common health stressor. In the absence of understanding the root causes of PM_{2.5} air pollution, students may feel helpless at mitigating the resultant regular disruptions in their daily lives. This innovative lesson conducted by the STEM extracurricular club in Naresuan University Demonstration School pairs an inquiry-based iterative approach to exploring the root causes of PM_{2.5} pollution in Northern Thailand with the development of solutions that are unique to the students' everyday experiences and their community's needs. The lesson also demonstrates how the selective use of simulations, interactive online courses, and design thinking fosters creativity, curiosity, and other 21st-century skills.

In this chapter, we learn:

- ✓ The main causes and health risks of PM_{2.5} air pollution in Northern Thailand
- ✓ How to structure a five-part STEM module contextualised to Northern Thailand using the principles of design thinking
- ✓ How to integrate simulations and hybrid learning into a module to foster content mastery and hypothesis formulation
- ✓ A scaffolded and iterative method of innovating solutions to public health risks



Students in Thailand's Lower Northern region confront a severe, seasonal environmental crisis: dangerously high levels of PM_{2.5} pollution during the dry season. From January to March, the dry season coincides with the harvest of rice and sugarcane in Northern Thailand. This is the same for the agricultural hub of Phitsanulok, within which widespread field burning occurs.

Driven by a need for efficiency and cost reduction, farmers burn sugarcane to remove the leaves and speed up the harvest process. They also burn rice stubble to clear land for the next cycle. This practice contributes significantly to regional air pollution, which is further exacerbated by frequent temperature inversions. During such events, cold air and pollutants become trapped near the ground and are prevented from dispersing due to a layer of warm air that forms and acts as a lid. This pervasive issue jeopardises public health and disrupts daily life, hindering work and the provision of education, and ultimately negatively impacting economic stability. In such contexts, a critical question arises: How can our students meaningfully address this complex problem, and are they adequately prepared to be competent agents of change? As such, education must rise to this challenge, to provide opportunities for learners to deeply engage with practical applications necessary for genuine societal impact.

Tackling real-world issues like PM_{2.5} pollution demands an interdisciplinary approach. While scientific understanding is fundamental to comprehending the underlying phenomena, the unique geographical, economic, social, and cultural nuances of each affected area necessitate strong technological and mathematical competencies — to gather and analyse real place-relevant data, providing a nuanced understanding of local conditions. Furthermore, the inherent complexity of these problems requires a systems thinking approach — a core tenet of engineering education — to identify interconnected factors and potential leverage points for intervention.

It is within this nexus of Science, Technology, Engineering, and Mathematics (STEM) that we find a powerful framework for cultivating student agency. This chapter details Naresuan University Demonstration School's implementation of "place-based problem solving with real-world simulations and data collection," an approach designed to equip students with the knowledge, skills, and disposition to become active, effective agents in addressing the critical issues facing their own communities.

Topics covered in this lesson

Environmental science & health

- Understanding the nature of PM_{2.5}, its sources, and its direct effects on human health

Mathematics, exponents, & scientific notation

- Quantifying PM_{2.5} particles in micrometres
- Understanding and using statistical knowledge to present data and interpret them for decision-making

Scientific simulation & data analysis

- Manipulating variables in simulations to observe pollution dynamics and interpret data that affects air quality
- Using statistical knowledge to present data and interpret statistical values for decision-making

Systems thinking

- Using tools like SageModeler to map out the causes and effects of environmental problems systematically

Solution design

- Proposing evidence-based solutions in actionable environmental awareness campaigns focused on promoting healthy breathing environments

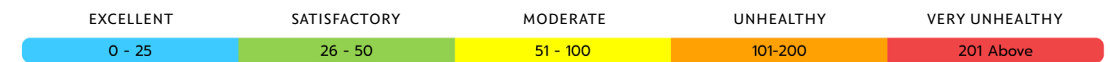
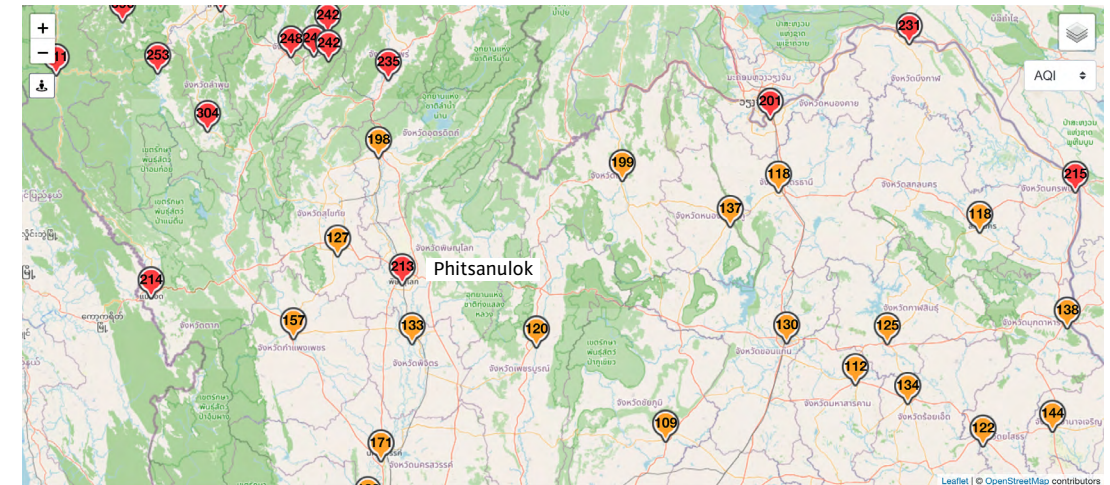
Geography & topographical analysis

- Comparing and analysing topographical maps to identify the correlation between physical features of the basin-like terrain and the accumulation of PM_{2.5} pollutants (prior knowledge)

Seasonal air pollution in Lower Northern Thailand

Northern Thailand experiences high levels of PM_{2.5}, peaking during the January to March dry season. The primary source of this pollution is driven by agricultural burning, specifically for sugarcane and maize cultivation. The region's basin-like topography exacerbates the issue by trapping the smoke and particulate matter, leading to prolonged exposure that can negatively impact the local communities.

Since June 2023, the Thai Pollution Control Department (PCD) has revised the safety threshold for PM_{2.5} at 37.5 µg/m³ for up to 24 hours of exposure. However, this limit is often exceeded in the dry season, with PM_{2.5} readings reaching two to three times greater than the safe threshold. This leads to “Unhealthy” (Orange) or “Very Unhealthy” (Red) Air Quality Index (AQI) levels in some areas.



AQI in Northern Thailand on 3 April 2026, 22:00

Existing regulatory frameworks, such as the Zero Burn prohibition and price penalties, have failed to gain traction due to conflicting economic challenges or pressure. For many farmers, the financial penalties from burning frequently outweigh the high costs of manual labour and/or machinery. Additionally, these financial barriers are compounded by traditional beliefs that burning eliminates pests and speeds up the harvest cycle, hindering efforts to elicit behavioural change.

This lesson takes on a systems-based approach to analysing the air pollution crisis in Northern Thailand. By integrating Environmental Science and Mathematics, students will explore and problem-solve practical, scalable solutions through an interdisciplinary lens.

Catering for mixed student readiness

This lesson was conducted as part of extracurricular activities in a STEM interest club. The club consists of students ranging from 15–17 years of age. Teachers addressed mixed student readiness in three ways:

1. Having small project groups (2–3 students) to encourage peer support
2. Using code-free tools like SageModeler to reduce the barrier of entry
3. Providing templates and worksheets such as the SCQA worksheet for scaffolded instruction



SCAN TO ACCESS
Real-time data
of Thailand's
AQI






Smoke from agricultural burns carries PM_{2.5}





Lesson plan

Designing solutions for managing agricultural waste

i. Desired learning outcomes and objectives

Desired learning outcomes	Rationale
 <p>1. Develop a comprehensive understanding of the complexities underlying a local environmental issue</p>	<p>This requires students to acquire specific content knowledge about the sources of PM_{2.5}, seasonal variations in particulate levels, and the meteorological, socio-economic, and cultural factors influencing air pollution in their community. This moves them beyond a generic understanding of air pollution to a context-specific one.</p>
 <p>2. Apply interdisciplinary STEM knowledge and skills to solve a community-based (real-world) problem</p>	<p>This is core to the STEM learning framework, anchoring students' learning in their local contexts to encourage agentic problem-solving and community-based change.</p>
 <p>3. Utilise data collection, simulation, and analysis for informed decision-making</p>	<p>This focuses on developing students' 21st-century skills, in particular data literacy, digital literacy, and critical thinking.</p>
 <p>4. Engage in systems thinking to explore a complex issue</p>	<p>This is a key competency in addressing complex problems. It moves students from a linear cause-and-effect approach to understanding how systems are interconnected.</p> <p>Students learn how changes in one part of a system can affect other systems and the overall picture. This enables them to develop more realistic and sustainable solutions.</p>

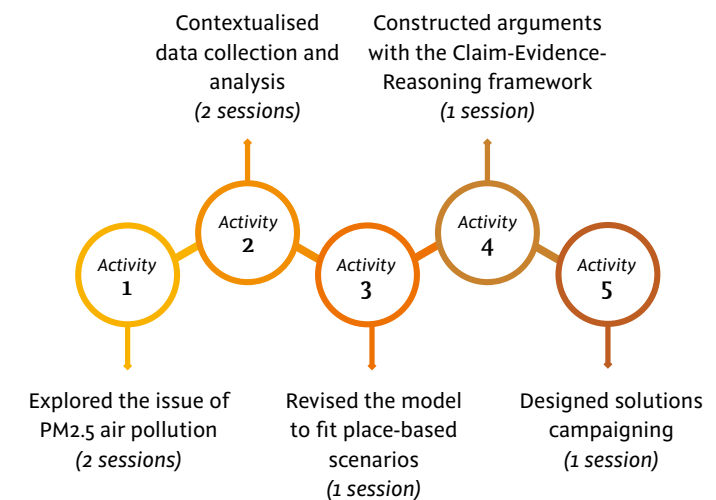
Desired learning outcomes	Rationale
 <p>5. Demonstrate agency and responsibility in addressing community challenges</p>	<p>By brainstorming solutions and developing action plans, students are encouraged to move away from passive learning towards active participation, fostering a personal sense of empowerment and responsibility towards their local environment and making a positive change.</p>
 <p>6. Communicate complex findings and propose solutions effectively and convincingly to a diverse audience</p>	<p>Students demonstrate their ability to translate complex scientific and mathematical concepts into accessible information, to raise awareness in their local communities and encourage collective and sustainable action.</p>

ii. Carrying out the lesson

The 10-hour session was structured around 5 key activities (approximately two hours per activity). They were sequenced to guide students through a place-based problem-solving process using real-world simulations and data.

Design thinking was used as an overarching approach to structure the five activities. This framework guided students through a structured problem-solving journey, beginning with empathising and defining a problem, to ideating solutions, prototyping, and presenting a final revised solution.

It was structured as such:



Activity 1
Exploring the issue of PM2.5 air pollution

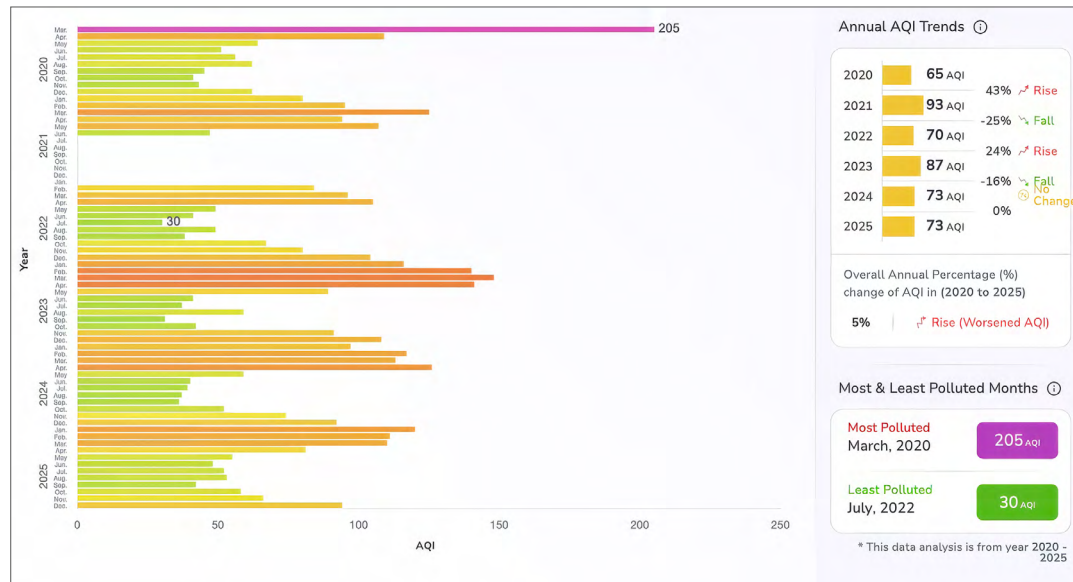
Materials used:

- Visual aids illustrating particle sizes comparative to PM2.5
- Calculator
- Worksheets with examples for applying exponents and scientific notation to particle sizes
- Individual laptops or computers

Session 1

a. Problem contextualisation

The learning experience began with the teacher introducing and contextualising the problem of air pollution, based on students' lived experiences. Discussions were initiated by showing a photo of air pollution caused by PM2.5 smog in Northern Thailand, and students were asked to share their experiences on such incidences.



Live data on air pollution in Northern Thailand

b. "Photo voices" storytelling and peer sharing

Students then engaged in a "photo voices" storytelling activity, where they sourced for and put together a series of photos to show how air pollution has affected their lives in pairs, sharing perceived causes, before repeating this process in a new pair. Many of these photos were taken by students themselves from the annual haze during each dry season. Reflecting on their personal photos provided significant insight(s) into students' awareness and background knowledge.



Students sharing their experiences of air pollution through photos

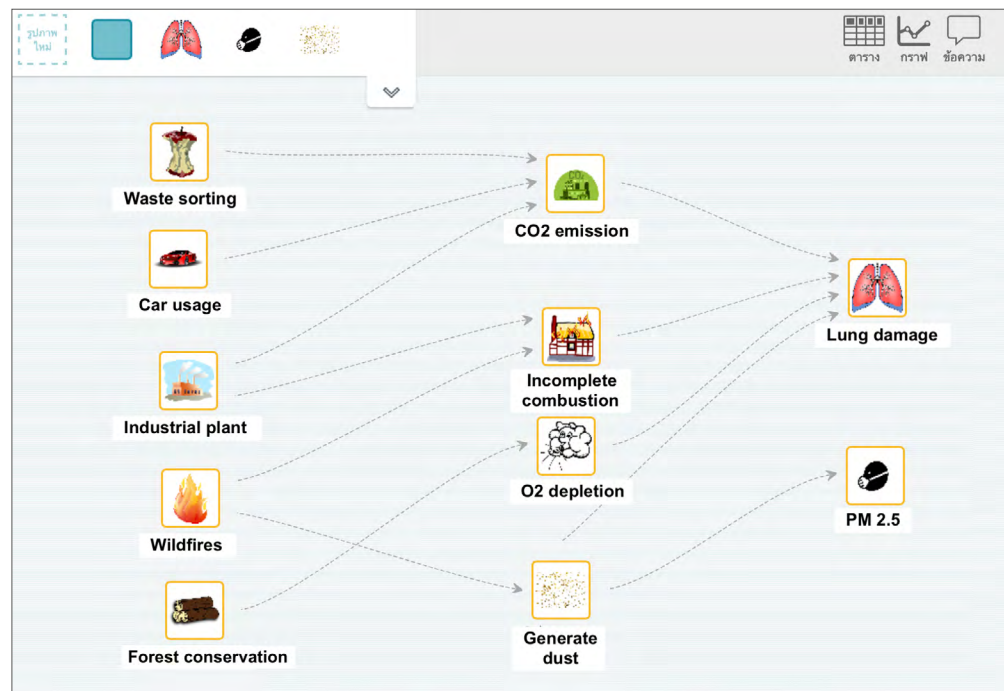
After the pair-to-pair sharing, students jotted down their perceived causes of the air pollution, noting their own stories and what they had learnt from their peers. The teacher guided the reflection process by providing guiding sentence structures, such as: "The smog is caused by... it affects... so I feel..." This encouraged students to move beyond surface level descriptions and link their knowledge on the causes of the air pollution to its social impacts, and their own affective (emotional) responses.

c. Hypothesis modelling with SageModeler

Students were then guided to create a flow diagram using SageModeler, to represent their hypothesis on the causal relationships between factors related to PM2.5 air pollution in their area.

The teacher assured them that the factual accuracy of their model was not a key factor, highlighting that the model should instead represent their thoughts and ideas on the causes of the pollution thus far.

Students then shared their hypothesis models with their peers.



A student's causal diagram created using SageModeler



Did you know?

SageModeler is a free, web-based, open-source software that allows the creation of systems modelling diagrams without the need for coding or mathematical formulas, making it a useful pedagogical tool for introducing systems thinking and modelling across all levels. Three types of modelling are available in SageModeler:

1. System structures and dynamics
2. Static equilibrium models
3. Dynamic time-based models



SCAN TO LEARN
More about
SageModeler

Session 2

a. Review

The teacher reviewed models created by students and introduced the need for **scientific/data-based evidence** to support their hypotheses.

Pedagogical considerations

- “**Photo voice**” **storytelling** is a powerful tool to contextualise real-life problems/issues to students’ lived experiences. In this lesson, students articulated the impacts of air pollution on their lives, while embracing the diverse perspectives of their peers in the community.
- For paired sharing, two or more cycles are recommended to ensure that every student has the opportunity to share their ideas. Time permitting, multiple cycles of sharing with different partners can expose students to **diverse perspectives** and allow them to **refine their communication skills**.
- Students may experience difficulties when communicating their personal experiences on complex issues. The provision of **leading statements** (such as sentence starters) can lower the cognitive load and allow them to move past the initial challenge of “how do I start” and delve into expressing their personal emotions and thoughts on how their real-life observations connect to the theoretical causes of air pollution in their community.
- Students were encouraged to **elicit and organise their existing knowledge using visualisation tools** like SageModeler. The diagrams helped them articulate their thought process and initial hypotheses visually, providing a foundation for review and revision.



SCAN TO ACCESS
The full Concord Consortium
lesson “Will the air be clean
enough to breathe?”

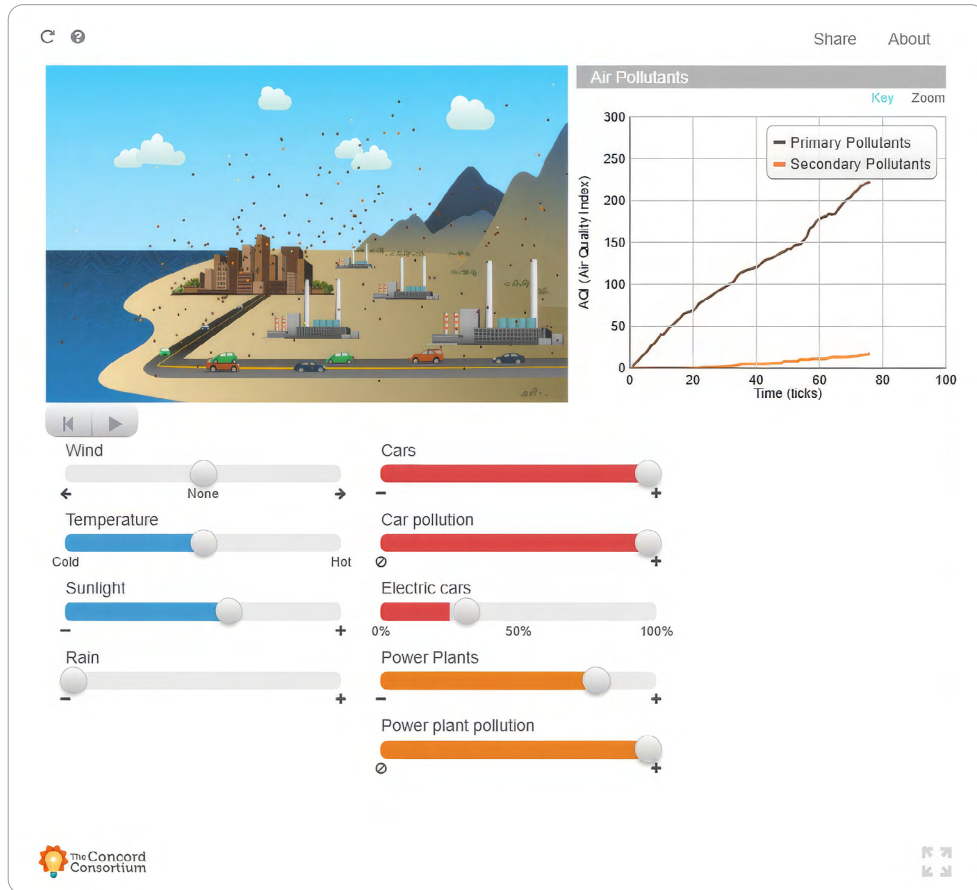
b. Investigation

To investigate the underlying causes of PM2.5 pollution and its effects on human health, students formed small groups of up to three students and worked through sections from the Concord Consortium’s lesson “**Will the air be clean enough to breathe?**” that were selected by their teacher for their focus on the causes and health impacts of pollution.

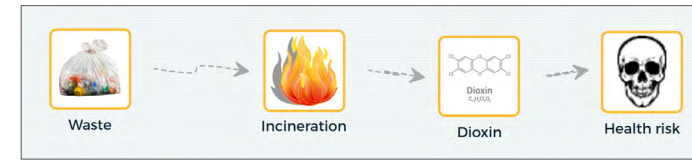
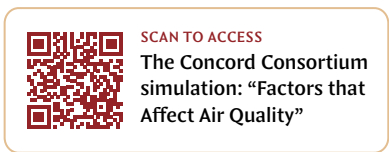
By working in small project groups, students shared their resources. This helped build a foundation for collaboration and support that can in turn promote collaborative decision-making and discussion.

Students completed six online activities that consisted of interactive simulations and real-world data to guide their exploration on factors that collectively degrade air quality. By the end of the module, the simulations were used to predict the long-term atmospheric impacts of human development.

Next, students explored another simulation titled “Factors that affect air quality”. In this simulation students manipulated various factors, such as the sources of pollution and the amount of pollution generated. They also explored the impact of alternative, cleaner transportation such as electric cars by toggling with the sliders to set up different conditions. Finally, they observed and discussed the effects of primary and secondary pollutants as represented by the black dots and orange dots in the model, respectively. Students addedly reflected on how their observations in the simulation may have differed from their original ideas.



Simulation: Factors that affect air quality

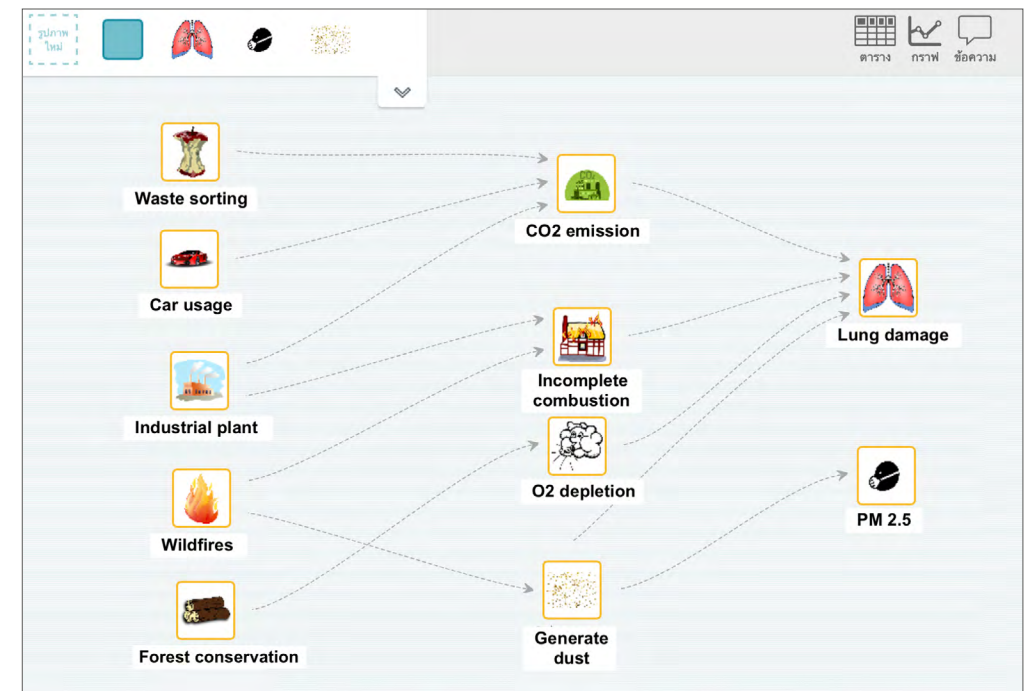


A causal diagram in SageModeler

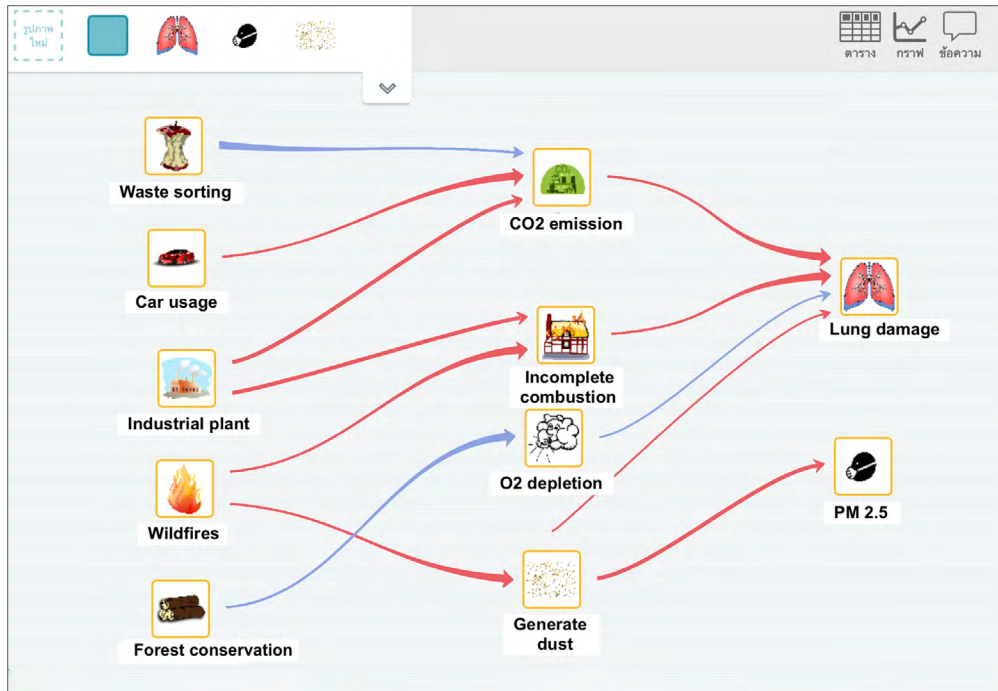
c. Model revisions

Following reflection on the observations made from the simulation and their learning on the factors contributing to air pollution, students returned to their hypothesis models and revised them. Missing factors and new quantitative relationships were added to the flow diagram. For information where empirical evidence or supporting data was insufficient, a dotted line was used to represent the unverified relationship.

In the revised model shown, the student incorporated additional factors and causal links and elaborated on the connections by specifying the quantitative relationships between the factors. These were informed by content knowledge derived from the online lesson and independent research from scholarly sources, to better explain the dynamics among the factors.



A student's initial diagram created using SageModeler



A student's refined diagram

The revised model demonstrated deeper cognitive engagement as they mapped the complex relational links between the various factors. For example, the arrow thickness represented the magnitude of impact, with thicker arrows representing a stronger causal effect, and red and blue arrows denoting positive and negative correlations.

Activities such as car usage, industrial plant operations, and wildfires lead to harmful outcomes like carbon dioxide emissions, incomplete combustion, and dust generation. These intermediate factors (indicated by red arrows) directly contribute to severe health impacts, specifically lung damage. In contrast, sustainable practices (indicated by blue arrows) like waste sorting and forest conservation are modelled as mitigating factors that reduce these emissions and their impact on PM_{2.5} levels.

The lesson came to a close with a teacher-directed summary of the day's activities and their key learning points.

Pedagogical considerations

Simulations are a useful educational tool for modelling scientific concepts. They allow students to safely and ethically interact with different variables to test their effect on phenomena that might be too dangerous or sensitive to be replicated or directly observed in a real-world setting.

Activity 2 Contextualised data collection and analysis

Materials used:

- Simulation: "Movement of Pollutants"
- Topographic map of Northern Thailand
- Localised data on air pollution in Northern Thailand
- Individual laptops or computers

Session 1

a. Review

The session began with a review of students' revised models in the previous activity. This was a collective activity where students presented their initial diagrams, and instructors offered probing questions to challenge unsupported claims (e.g., "Does the data support this link?") This enabled students to revisit the evidence and correct their misconceptions through thinking more critically, rather than passively receiving information.

b. Simulation exploration: "Movement of Pollutants"

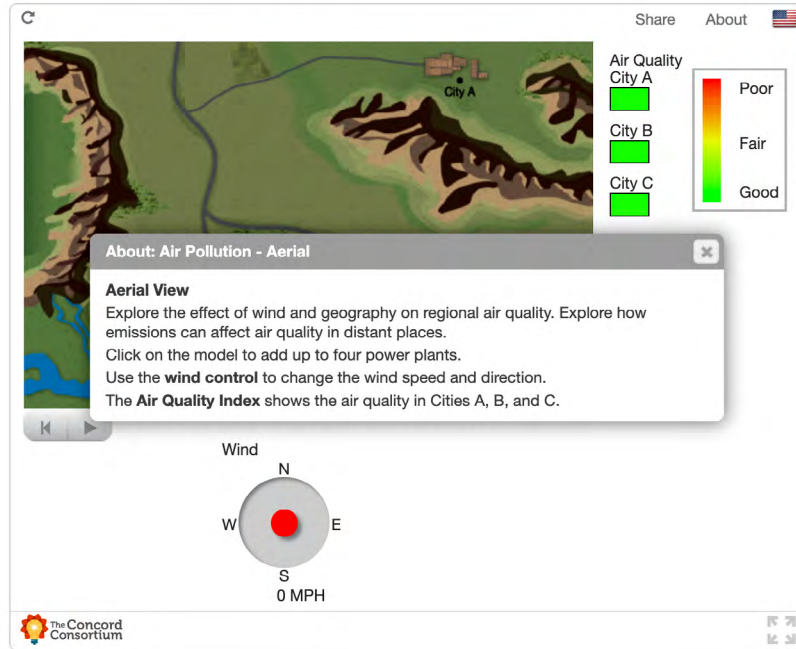
The teacher began the lesson by presenting the challenge of maximising good air quality with a brief demonstration on how to use the simulation tool "Movement of Pollutants". Students subsequently used the simulation to manipulate variables, such as wind direction and position of the cities, to explore how regional air quality can be improved. In doing so, students used their observations to analyse the cause-and-effect relationship between these variables.



Students engaging with the simulation

Movement of Pollutants

Can you place power plants so all three cities have good air quality at the same time when the wind is blowing from any direction? Investigate how mountains and wind direction affect air quality.



"Movement of Pollutants" simulation



SCAN TO ACCESS
The Concord Consortium
"Movement of Pollutants"
simulation

c. Mapping simulations to real life

Topographic maps of Northern Thailand were then provided. By comparing the simulation with the map of Phitsanulok, students were able to identify similarities between their geographical features.

Students used the information they deduced from the maps and their observations from the simulation to explain and draw conclusions on how pollutant movement can result in seasonal smog in Northern Thailand, even in areas distant from the pollution source.

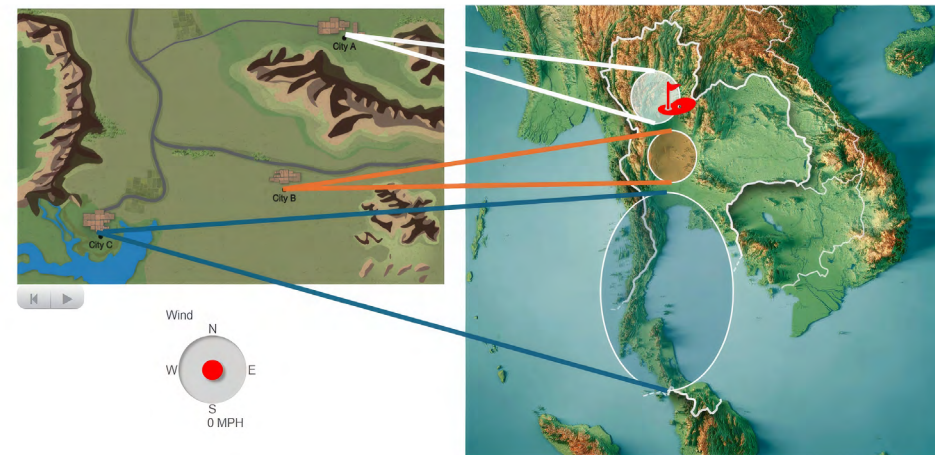
Next, students' learning was contextualised to their lived experiences as they compared the powerplants in the simulation to local sources of pollution, such as cars and agricultural burning. From this, they were able to draw a key insight — an "aha" moment — that as a region's geography is "fixed", the best approach to achieving a sustainable solution is to manage the source of the pollution.



Activating prior knowledge

As part of the national Social Studies curriculum, all Thai students are taught to read maps, understand aerial photos to identify physical features (Grade 6 Indicator 1), and analyse natural phenomena (Grade 6 Indicator 2).

(left) Student examining a topographic map of Northern Thailand
(below) Example showing a comparison between the simulation and the topographic map



Did you know?

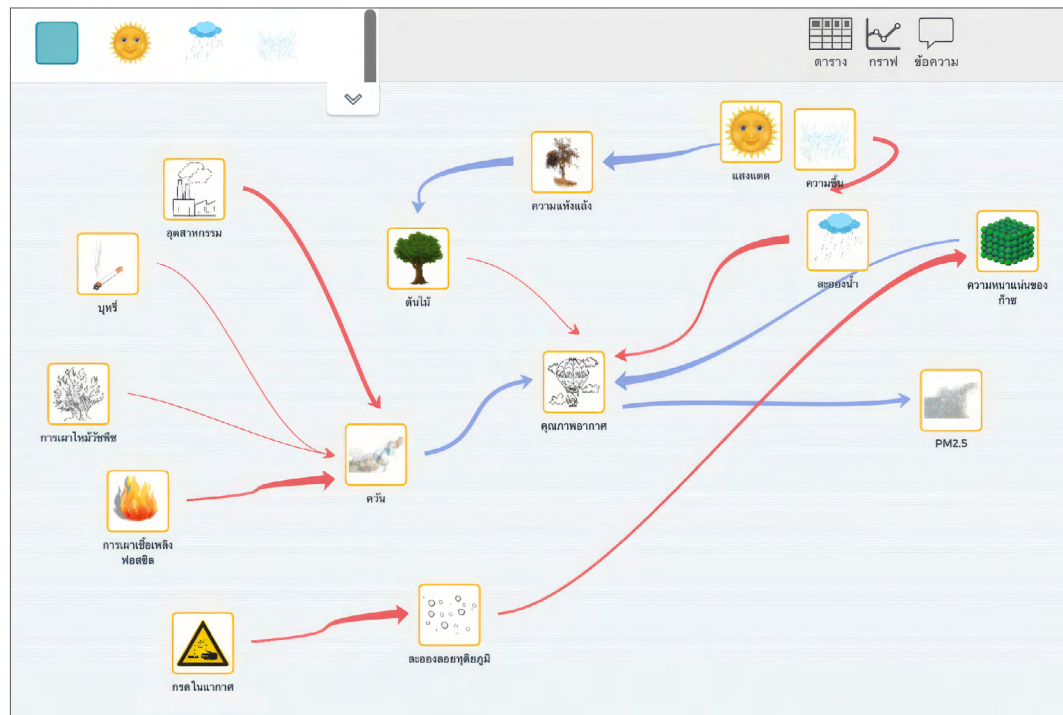
Seasonal air pollution in Phitsanulok generates significant biomass smoke; it is caused by agricultural burning, which is carried out as a means of clearing debris and accelerating harvest. The province's unique geography worsens this issue. Phitsanulok is situated in a low-lying basin bordered by the Phetchabun Mountains to the north and east. This mountain range acts as an orographic (physical) barrier that obstructs the dispersion of particulate matter and atmospheric pollutants, preventing the smoke and pollutants from escaping the area. During this season, the Northeast Monsoon winds carry additional smoke from neighbouring agricultural regions and countries into the basin. This influx, coupled with the lack of vertical airflow characteristic of temperature inversions, create a "trapping effect". This results in stagnant, polluted air pooling against the windward slopes of the mountains, leading to prolonged and severe haze episodes.

d. Model revision

Students created a customised simulation within SageModeler incorporating parameters specific to their local environment. By defining factors like “Basin Topography” and “Wind Direction”, they built a new model that simulated the atmospheric pollution behaviour within their community context.

Then, students engaged in peer discussion to identify any overlooked environmental drivers, such as sunlight, rain, wind strength, temperature, and more.

Following this, students iteratively revised their models, adding any missing factors that surfaced in their peer discussion. Lastly, they integrated quantitative relationships to define the magnitude of influence between the different variables, transferring their conceptual map into a data-driven simulation.



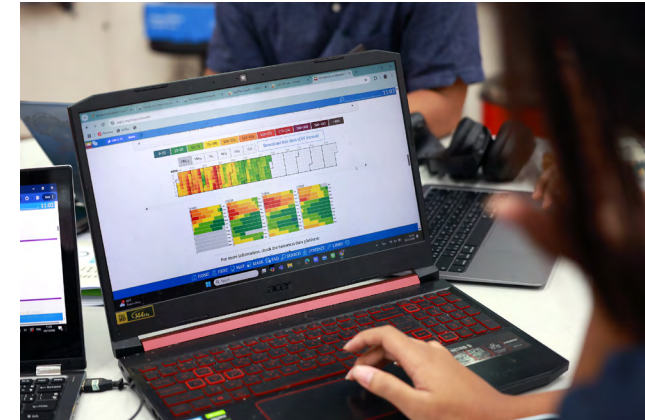
An example of a revised model in which sunlight was added as a primary contributor

Session 2

Next, students were presented with empirical air quality index datasets from Phitsanulok, Thailand. They were tasked with validating their models by using the real-world figures to justify their model design.

Pedagogical considerations

To bridge the gap between theoretical understanding and local context, *real-world data* from their community was used to complement the simulations, allowing students to correlate observations in the simulation to real-world evidence and phenomena.



A student examining air quality index data from Phitsanulok, Thailand

Activity 3 Model revision to fit place-based scenarios

Materials used:

- SageModeler
- CODAP
- Individual laptops or computers

The teacher introduced students to Common Online Data Analysis Platform (CODAP), a tool for data visualisation and analysis.

The teacher introduced and demonstrated how to use key functions in CODAP, specifically, how to group data points and generate graphs to reveal trends. By calculating the frequency distributions, means, standard deviations, and variances, students were able to quantitatively characterise local pollution patterns and seasonal fluctuations in PM2.5.

Given the information gained from data analysis, students were given another opportunity to revise their models, adding factors or adjusting the magnitudes of the variables where needed. Once again, information that they had yet to know or areas in which evidence was lacking were represented with a dashed line.

Did you know?

CODAP is an open-source software for data analysis and visualisation that stands for Common Online Data Analysis Platform.



SCAN TO LEARN
More about
CODAP

Pedagogical considerations

Students were prompted to *revisit and refine* their SageModeler diagrams at various junctures. In particular, these junctures aligned with activities in which new information or insights were revealed. This fostered a mindset of *iterative improvement* and encouraged students to grow in their own learning by reflecting on and reviewing their understanding.



Student voice

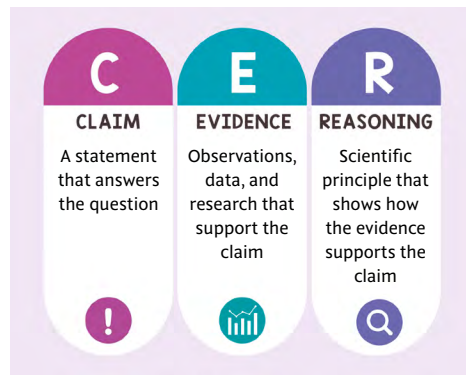
“The simulation helped me review my prior knowledge. It showed that mountain placement and local wind direction are interconnected in determining the levels of air pollution. If the wind direction changes, the level of air pollution can change too. The simulation and topographical map also helped me understand why the Phitsanulok area experiences this kind of pollution and how intense heat can significantly change our air quality. Phitsanulok’s air quality is different from other northern regions because its rural landscape is flatter with fewer mountains. This is why it doesn’t have as many problems as mountainous areas like Chiang Mai, where my hometown resides.”

Activity 4
Constructing arguments with the Claim-Evidence-Reasoning framework

Materials used:

- SageModeler
- Individual laptops or computers

In this session, students worked in groups to create a diagram that presented their collective hypothesis on the causes of air pollution in Phitsanulok, Thailand. They did this by merging their individual models into a single model that the group had agreed on.



The Claim-Evidence-Reasoning (CER) framework

To do this, they were guided to use the Claim-Evidence-Reasoning (CER) framework. Each student proposed a claim, with evidence and their reasoning for how it causes air pollution. Accepted claims backed by sound evidence and reasoning were added to the group’s diagram. In the case where a claim was presented with incorrect evidence and reasoning, teachers prompted students with questions to reflect on the reliability and source of their evidence, and guided them to revisit and revise their claims as needed.

This process facilitated debate on the viability of the claims and encouraged them to look into gathering more supporting data to validate their claims, and incorporate only those that had substantial evidential support.

Pedagogical considerations

The teacher plays a crucial role as a *facilitator*, guiding students to question, critically examine their assumptions, seek evidence, and refine their understanding rather than passively accept given answers or information.

Activity 5
Solutions campaigning

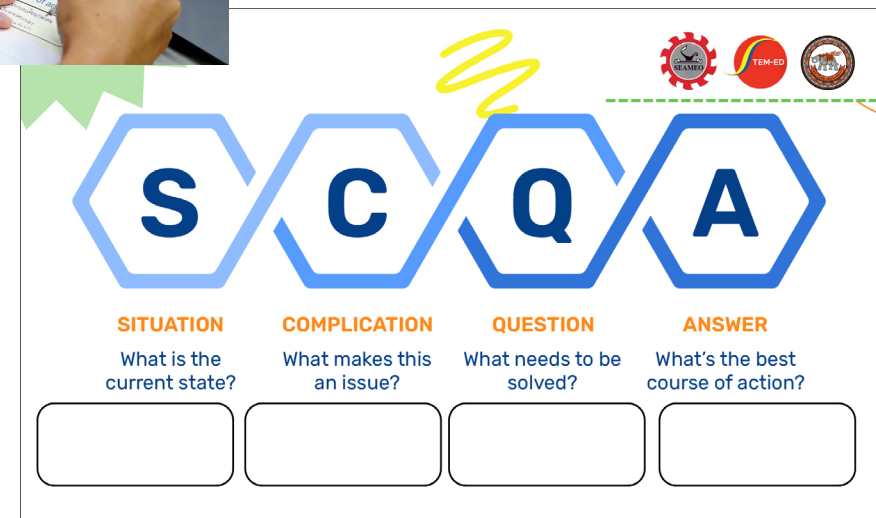
Materials used:

- SageModeler
- SCQA worksheet
- Campaign proposal worksheet

a. Synthesising information

Students worked in their groups to review their collective hypothesis model and consolidated the most impactful causes of air pollution they had agreed on using the Situation, Complication, Question, and Answer (SCQA) worksheet provided. This worksheet guided students to organise their knowledge into a cohesive story to support their model design. Templates such as the SCQA worksheet can be used to provide scaffolded guidance for complex tasks that involve multiple variables.

Following this, students iteratively revised their models, adding any missing factors that surfaced in their peer discussion. Lastly, they integrated quantitative relationships to define the magnitude of influence between the different variables, transferring their conceptual map into a data-driven simulation.

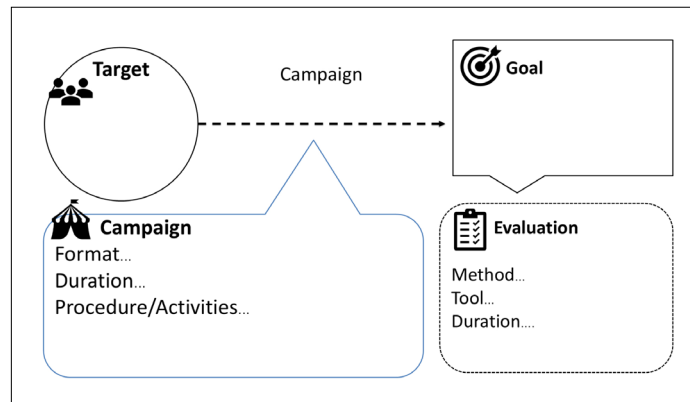
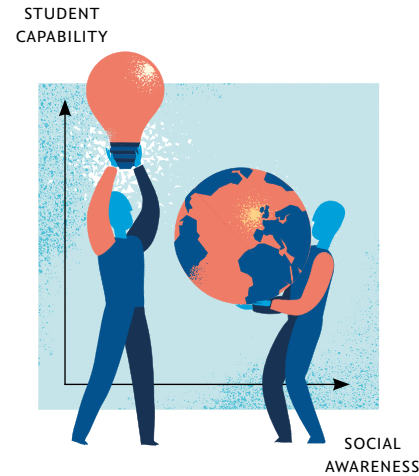


SCQA worksheet template

b. Creating new value

Students were also encouraged to generate as many new ideas as possible to develop an environmental awareness campaign that raises public awareness on the causes of air pollution. Each student was tasked to generate 5–10 ideas and used an idea prioritisation matrix to narrow down their selections. The matrix prioritised two key criteria: (1) student capability, assessing the practicality and feasibility of task completion, and (2) social awareness, evaluating the campaign’s potential for societal impact. This ensured that the shortlisted ideas were both meaningful and achievable within the constraints of time, resource availability, and student readiness.

Groups were then tasked to select one idea and develop a campaign proposal on the root causes of PM2.5 air pollution in Phitsanulok, with the intention of presenting their proposal to the school administrator.



Campaign proposal worksheet

c. Presentation

Finally, each group presented their hypothesis model and campaign proposal to an audience.

Student voice

“Through this process my group devised an idea to create an app that allows people to understand the causes and consequences of daily air pollution. I wanted to make it easy to understand how fine dust, which is tiny and hard to see, is generated. The target users are middle school students. We need to appeal to them in a way that makes them feel engaged, enjoy the process, and remember the information learnt. The app can have a butterfly effect...”



A student group presenting their campaign proposal

Pedagogical considerations

- The campaign proposal worksheet was designed with specific headers to offer students some *scaffolding for organisational guidance*, helping students to structure their arguments effectively, without restricting their creative autonomy in planning their proposals. Further scaffolds can be offered at appropriate junctures when needed.
- By designing a *place-based learning journey* contextualised to students’ lived experiences, students were empowered to take action through creating their own environmental awareness campaigns.

iii. Challenges and solutions in lesson implementation

Challenge	Potential solution
1. Students may have difficulty constructing their initial hypothesis models	SageModeler is a useful tool in helping students translate their thoughts into a diagram. Encourage students who are struggling to share their thoughts with peers, jot down their ideas, before collectively working to translate them into a sequenced diagram.
2. Fostering the habitual practice of iterative reflection and refinement among students	Make model revision a routine by assigning it as a task at the end of each session, ensuring students take time to revise their model with the new information gained.
3. Students may feel uncomfortable sharing their opinions with others, especially those they are not familiar with	Make room to encourage diverse perspectives on the same topic. The “photo voice” activity can act as an ice breaker that allows students to share their personal experiences more comfortably with others, while they practise listening and being open to the ideas of others.
4. Students may jump too quickly to a specific solution without considering alternative perspectives and gathering sufficient supporting data	Encourage students to generate multiple possible ideas before shortlisting the most feasible options. Guide them to prioritise relevant and impactful causes and their effects by asking “So what?” as a guiding question.
5. Implementing the campaigns generated from this session may impose additional burdens on the teaching team, such as having to navigate school policies, permissions, and securing budget and time	Writing a clear proposal and action plan helps convey the benefits of the campaign to school administrators. Guide students to explore low-cost options and leverage existing school and community initiatives and infrastructures. Using an “idea prioritisation matrix” helps students consider more pressing ideas and assess the projected impact of their proposal.



Authors’ reflections

This study offers students an opportunity to raise awareness on environmental issues in their local community. It emphasises the importance of complementing knowledge construction with evidential support from real data. This approach helps students recognise the relevance of discipline-specific knowledge such as Mathematics (data analysis) in everyday life. Additionally, by linking mathematical concepts to environmental issues, students can see how various subjects work together, making their learning more meaningful.

In this lesson, the learning modules from the Concord Consortium act as a helpful initial resource to develop students’ scientific reasoning. Encouraging students to then create diagrams to represent their understanding helps translate and represent their thoughts in a format that is easier for others to understand. Involving students in the Claim-Evidence-Reasoning exercises also fosters idea exchange with their peers, decision-making to build a shared understanding, and encourages peer evaluation. Teachers can develop students’ critical thinking skills by encouraging them to revisit their claims through questioning.

Through this place-based STEM lesson, students integrate Science, Technology, Mathematics, and Systems Thinking to solve local problems. Supported by pedagogical strategies and digital tools (e.g., CODAP and SageModeler) acquired through the SEAMEO STEM-ED SEA-TEP programme by SEAMEO STEM-ED, students move from basic knowledge construction to evidence-based reasoning. This approach makes learning meaningful by linking mathematical analysis to real-world environmental impacts, ultimately fostering the critical thinking skills needed for innovative, community-specific solutions.

Dr Artorn Nokkaew, Ms Suparat Chuechote, & Dr Thanyaluck Ingkavara

From Shortage to Innovation: A STEM Hackathon to Tackle Singapore's Eldercare Challenges

Dr Melissa Neo



INSTITUTIONAL PROFILE

**National Institute
of Education,
Nanyang Technological
University**

LOCATION

Singapore

TYPE OF INSTITUTION

Teacher education and training

LESSON DETAILS

NUMBER OF LESSONS

1 lesson

DURATION

8 hours/lesson

GRADE LEVEL

Year 1 to 3 undergraduate students

SUBJECT/ DISCIPLINE

STEM (Science as the lead discipline)

NO. OF STUDENTS/ PARTICIPANTS

30 (5 students per group)

STUDENT READINESS

Mixed to high ability

By 2030, one in four of Singapore's population will be aged 65 and older.¹ As the country experiences a demographic shift towards a silver tsunami, this translates into downstream challenges such as rising healthcare costs and a higher demand for eldercare facilities and services amidst a shrinking workforce.² In this chapter, Dr Melissa Neo guides us through running a full-day hackathon for pre-service teachers to innovate solutions for an ageing society. The hackathon grounds students' learning in a culturally relevant and pressing issue, coping with an ageing population, pushing them to problem-solve and develop sustainable solutions contextualised to the Singaporean eldercare landscape.

In this chapter, we learn:

- ✓ The challenges of managing an ageing population and the state of eldercare in Singapore
- ✓ How a single-day STEM hackathon for undergraduate students contextualised to a local challenge can be implemented
- ✓ How a group of students leverage the STEM Quartet instructional framework to navigate the hackathon process and design an innovative prototype
- ✓ How a STEM hackathon can be implemented for pre-service teachers to gain practical insights for integration into their future classrooms

Each year, the Multi-Centric Education, Research and Industry STEM Centre at the National Institute of Education (meriSTEM@NIE) in Singapore hosts a theme-based STEM hackathon in collaboration with Sci-Napse, a student-led community for pre-service teachers at NIE. First- to third-year undergraduate students are highly encouraged to

1. Ministry of Health, *Action Plan for Successful Ageing 2023*, (n.d.), <https://www.moh.gov.sg/others/resources-and-statistics/action-plan-for-successful-ageing>
 2. "Singapore's silver tsunami: Elder care spending to skyrocket to \$49b per year by 2030", *Healthcare Asia Magazine*, 22 February 2022. <https://healthcareasiamagazine.com/healthcare/news/singapore%E2%80%99s-silver-tsunami-elder-care-spending-skyrocket-49b-year-2030>

participate in one or more STEM hackathons during their academic journey, ensuring a diverse mix of students from different grade levels and subject specialties.

The one-day hackathon is an initiative designed to provide students with an opportunity to immerse themselves in a dynamic learning environment, to understand the mechanics of a hackathon, work collaboratively to explore STEM concepts, and adopt human-centred approaches to solve real-world challenges. This provides student teachers a window into the types of challenges that professionals in the STEM workforce encounter, an appreciation of how time constraint in a hackathon can build students' soft skills such as critical thinking, rapid prototyping, and effective communication, and personal experience and insights into the potential challenges that students may face when participating in STEM hackathon for the first time.

In the full-day STEM hackathon detailed in this chapter, student teachers from different STEM disciplines came together to tackle the issue of eldercare challenges in Singapore. They applied knowledge and research from across STEM disciplines to derive solutions such as:

- N-Power: An application-based smart watch for healthcare workers that enables biodata collection, AI scheduling, incident reporting, and monitoring by the supervisor
- Meditrace: An automated medication dispenser and alert system for each hospital ward to reduce risk of human error
- A virtual reality shopping market experience paired with an automated kitchen for personalised meals
- Elderbrew: An award-based automated drinks order and delivery service

Notably, as students were not constrained to developing a physical prototype, teams were empowered to focus on innovative, design-centric solutions. This resulted in a diverse range of creative solutions that were presented in various ways including STEM Quartet mapping, UI/UX diagrams, physical models, and conceptual virtual reality platforms.

Read more about the concept of hackathons as a tool for STEM engagement in chapter 1.4!



The Empowering STEM Education Professionals Programme (ESEPP) is an annual programme organised by meriSTEM@NIE. It encourages pre-service and in-service teachers worldwide to design and submit innovative, instructional lesson packages based on a given theme. The programme aims to enhance STEM education quality, foster a global community of passionate STEM educators, and promote the wider adoption of STEM in schools. It culminates in a learning festival where participants and competition winners, alumni, STEM experts, and industry partners can connect and share insights.



From the variety of solutions explored, these were the common areas of knowledge students tapped on within STEM:

Topics covered in this lesson	
Science	Technology
<ul style="list-style-type: none"> Common topics may include: <ul style="list-style-type: none"> Properties of materials Hygiene and sanitation Solution-specific topics may include: <ul style="list-style-type: none"> Circadian rhythm (sleep cycle) Pharmacokinetics and patient profiles (e.g., importance of dosage timing, drug-based interactions, drug allergies, etc.) Nutrition (and hydration) 	<ul style="list-style-type: none"> Common topics may include: <ul style="list-style-type: none"> Machine learning Optimisation algorithms Data security and cloud computing Solution-specific topics include: <ul style="list-style-type: none"> Natural language processing (e.g., for handwritten/digital prescriptions) Graphics rendering for the virtual reality interface Autonomous navigation
Engineering	Mathematics
<ul style="list-style-type: none"> Common topics may include: <ul style="list-style-type: none"> Use of sensors Integration of various systems (e.g., patient health data, real-time data collection and analysis from IoT devices, etc.) Solution-specific topics may include: <ul style="list-style-type: none"> Precision robotics Temperature (thermodynamics) 	<ul style="list-style-type: none"> Common topics may include: <ul style="list-style-type: none"> Modelling and pattern recognition for predictive functions (e.g., patient surges) Statistical and data analysis (e.g., to determine reliability of the machine for machine maintenance) Solution-specific topics may include: <ul style="list-style-type: none"> Reward based systems (e.g., for nutritionally sound choices)

Designing a STEM Hackathon

A hackathon can take on various formats and can be designed to accommodate approaches tailored to specific goals, audiences, and resources. Originating from the technology industry as a way to rapidly prototype functional solutions, hackathons are increasingly used in schools to enhance interdisciplinary learning and cultivate innovation and 21st-century skills.

As elaborated in chapter 1.4, designing a hackathon entails the following main steps:

Objective	Example in this hackathon
1. Establish a clear purpose or primary goal for the hackathon and identify the target participants	This hackathon involved pre-service teachers from various disciplines (e.g., Mathematics, Biology, Chemistry, Science, Physics). The session demonstrated how hackathons can be a practical model for STEM implementation in schools , and provided hands-on experience for future educators to reflect on pedagogical strategies for integrating interdisciplinary thinking into their own classrooms.
2. Establish the optimal duration of the hackathon and select a venue	As the hackathon takes on a single-day format, finding a common timeslot among students from differing disciplines was challenging. To mitigate this, the workshop was held on a Saturday at the National Institute of Education, in a space where tables were large enough and comfortably spaced for group collaboration and prototyping.
3. Craft the problem statement, context, or scenario	To contextualise Singapore's eldercare crisis, the briefing featured a video excerpt from a Channel News Asia documentary. This was paired with data on the care needed for managing a growing ageing population. Together, these framed the challenge around the objectives of optimising or reducing manpower and enhancing quality of eldercare.
4. Plan a detailed programme	To ensure smooth operations on the day of the hackathon, an internal programme was developed by the organising team. This included information such as food and beverage vendor details, staff reporting times, roles and responsibilities, inventory tracking for hackathon materials, and more.
5. Organise incentives	To incentivise participation, Club Sci-Napse organised three voucher-based awards. The selection of the vouchers was delegated to the student committee to ensure that the incentives remained relevant and appealed to their peers.
6. Gather feedback	Student feedback was gathered via a QR code at the closing of the event. This was used to inform future iterations of the pre-service hackathon. Additionally, an informal post-event debrief was held by the organising committee to surface operational insights and areas of improvements.



A winning team receiving their voucher prizes

In this chapter, Dr Melissa outlines how a single-day hackathon was designed and executed for a cohort of primarily first-year Mathematics university students.

Did you know?

STEM hackathons can be tailored to various student grade levels and abilities, extending beyond a singular focus on the “hacking” process. By integrating learning journeys with industry partners, these events can effectively broaden students’ understanding of the STEM workforce and help them recognise the relevance of STEM education to their future learning and career pathways.



SCAN TO READ
About a one-day STEM hackathon and learning journey for grade 9 students in Singapore



Lesson plan

Designing a STEM hackathon for eldercare solutions

i. Desired learning outcomes and objectives

Desired learning outcomes	Rationale
<p>1. Students address an authentic, culturally-localised, and relevant real-world problem.</p>	<p>Students connect and empathise with problems through problem-based learning. The process of PBL is student-led and student-centred in nature, promoting self-directed learning and accountability.</p>
<p>2. Students generate their own questions and conduct research on gaps or challenges with current solutions.</p>	<p>Through inquiry-based learning, students critically analyse and evaluate existing solutions.</p>
<p>3. Students define the specific aspect or issue they would like to address, and brainstorm to create a novel solution. They can also modify existing solutions, engaging in a feedback loop as they refine their solution.</p>	<p>Students undergo the iterative process of design thinking as they develop their critical thinking skills, resilience, and perseverance.</p>
<p>4. Students exercise open-mindedness, consideration, and respect for their peers’ ideas and opinions.</p>	<p>Students engage in collaborative learning, working on being open to diverse ideas and opinions.</p>






As the hackathon is open to undergraduate pre-service teachers from their first to third years of study, there is a diverse mixture of students with different subject specialisations (i.e., English, Mathematics, Biology, Chemistry, Physics, General Science) and levels of knowledge and skills. While each individual brings a unique set of prior knowledge, their common foundational basis is rooted in their secondary school education.

The hackathon's design leverages this academic heterogeneity to foster interdisciplinary collaboration that is representative of the modern STEM workplace. The hackathon featured in this lesson was largely attended by first year Mathematics students who comprised two thirds of the participants.

ii. Carrying out the lesson

This was a single-day STEM hackathon designed with the following parameters:

- 
Creativity and innovation: Physical prototyping was not mandatory. This enabled students to move beyond the physical limitations of the venue and budget to incorporate existing or emerging technologies into their visual prototypes.
- 
Student agency and autonomy: Students were empowered to define their own problem statements within the broader eldercare and manpower context. The process was student-directed, with facilitators adopting a consultative role while students managed their own research, timelines, targets, and expectations.
- 
Pedagogical reflection: The hackathon served as an immersive experience for pre-service teachers to gain insights into the student experience. This allowed them to evaluate the mechanics and logistics of a hackathon and reflect on pedagogical strategies for integration into their future classrooms.

Pre-Hackathon preparations

Strategic pre-event planning and coordination are essential to ensuring a seamless experience. The table below outlines preparations carried out for this pre-service hackathon.

Organising Team	Club Sci-Napse
<ul style="list-style-type: none"> Liaised with Club Sci-Napse chair and organising team to determine the hackathon purpose, theme, challenge, and programme Reserved date and venue for hackathon Invited judging panel Conducted team briefing Ordered, tracked, and packed materials for: <ul style="list-style-type: none"> Brainstorming session Prototyping supermarket Conducted audio and technical checks (e.g., tested the microphone, projector screen, and computer system) Liaised with food and beverage vendors Prepared slide deck for hackathon briefing Developed and prepared marking rubric for judging panel 	<ul style="list-style-type: none"> Student participant recruitment Hackathon facilitator recruitment (i.e., club members and hackathon alumni) to co-lead the session alongside faculty Award incentives (sponsored by meriSTEM@NIE) Participant reflection questions to encourage professional growth with a focus on: <ul style="list-style-type: none"> Effective communication and collaboration Evaluation of team practices to identify pedagogical strategies for integrating similar interdisciplinary experiences in their lesson design

Lesson 1 Welcome briefing (10 mins)

The programme schedule, learning objectives, goals, expected deliverables, and judging criteria were shared with students at the welcome briefing.



Students sat in their groups during the welcome briefing

Today's Deliverables: Idea Pitching (15 min per team)

- Presentation** 5 min - Understanding the problem and specifying requirements to solve the problem
- Proof of Concept / Prototype** 5 min - Demonstrate technical viability, intuitive interface, inclusivity, and real-world implementation potential
- Question & Answer** 5 min - Q&A by judges

Criteria for Judging

Criteria 1-3 by NSSE judges
Criteria 4 by Club Sci-Napse

- 1 Problematising**
 - Identifying and understanding the problem
 - Specifying requirements to solve the problem
- 2 Proof of Concept / Prototype**
 - Technical viability
 - Intuitive interface and navigation
 - Inclusivity
 - Scalability, sustainability & real-world implementation potential
- 3 Presentation & Q&A**
 - Logical and coherent flow
 - Supported by evidence, e.g., research findings etc.
 - Demonstration of sound STEM knowledge
- 4 21CC in Action**
 - Communication, Collaboration & Information Skills

Actualising Ideas in a Hackathon

Lacey, L. (2025). POC, Prototype, MVP: How to Start Small. <https://raltware.com/blog/mvp-prototype-poc/>

	POC	vs	Prototype	vs	MVP
Main goal	To test the feasibility of an idea or assumption		To provide stakeholders with a visualization of your product		To gather user feedback and find a product-market fit
Answers the question	Can we build that?		How can we build that?		Is it a product that consumers want?
Form it takes	Code-related test (sometimes demo or animation)		Interactive mock-up e.g. clickable walkthrough on Figma		Working model of your product
Risk reduction	Prevents you from making technical mistakes during development		Prevents user-dissatisfaction by allowing you to visualize and tweak the UI/UX		Prevents you from wasting resources on building a product that nobody wants to buy

Students were briefed on the expected deliverables, judging criteria, and judging allocations

Students were briefed on the expected deliverables, judging criteria, and judging allocations

Facilitators for this hackathon included faculty, student leaders from Club Sci-Napse, and hackathon alumni, bringing a diverse range of disciplinary knowledge and hackathon experience to assist the participants.

Lesson 2
Establish the context and present the STEM problem/challenge (20 mins)

In this hackathon, the theme chosen was **STEM for Humanity: Enabling STEM in Eldercare**. Students were presented with a synopsis and watched a video on a current issue or challenge in Singapore. They were given the following overview:

In as little as five years, one in four Singaporeans will be 65 or older, creating an urgent demand for as many as 24,000 more eldercare professionals. However, with an ageing workforce, the very sector needed to meet this demand is facing a critical shortage in manpower.

In this video, host Diana Ser immerses herself into the daily lives of eldercare workers to uncover the issues they face. Through expert insights, the video explores current and innovative solutions to optimise manpower, improve eldercare, and attract more people to a sector struggling with high burnout and a dearth of local professionals.

You have been tasked to work in teams of no more than five to design a STEM solution that addresses the manpower challenges and improves eldercare in Singapore.



SCAN TO WATCH
Inside Singapore's eldercare shortage

Pedagogical considerations

Value of student-led initiatives

Involving students in the design and implementation of a STEM hackathon has several positive implications. Students gain valuable insights into the event's logistics and structure, while cultivating a deeper understanding of the thought processes involved in crafting a compelling STEM challenge. This strategic partnership ensures that the STEM challenge proposed is relevant, engaging, meaningful, and more impactful for their peers.



Pedagogical considerations

By using a short section of a video from a credible source like Channel News Asia's *Talking Point*, students can gain a clear understanding of the eldercare crisis in Singapore. This approach grounds the problem presented in real human stories and expert insights, making it less abstract and more likely to evoke sympathy and motivation to problem-solve.

Lesson 3 STEM Hackathon — Brainstorming and prototyping (4 hours)

Materials used:

Materials for brainstorming and solution/prototype design

- Butcher paper
- Markers
- iPads or laptops
- Sticky notes

Materials for prototyping

- Cardboard sheets and mounting boards
- Aluminum foil
- Plastic bottles and containers of different sizes
- Straws of different diameters and lengths
- Satay sticks and ice cream sticks
- Glue, Blu Tack, and/or sticky tape
- Scissors and/or penknives
- Cutting boards

Students were encouraged to bring at least one iPad or laptop per team to facilitate their research and ideation process. Materials for brainstorming and solution/prototype designing/building were provided alongside lunch, snacks, and a hot drinks station. Students were given the autonomy to (1) manage their time and (2) either design and sketch a solution or create a proof-of-concept prototype.

To encourage student innovation, the hackathon was structured such that minimum guidance was provided. Students were empowered to find their own resources, which ranged from open-source libraries to digitally-accessible research materials such as news articles and statistical data. This approach provided space for teams to engage in discourse to evaluate the reliability of their chosen resources and reach a collective compromise or consensus. Instead, the facilitator's role shifted away from "instructor" to "consultant".

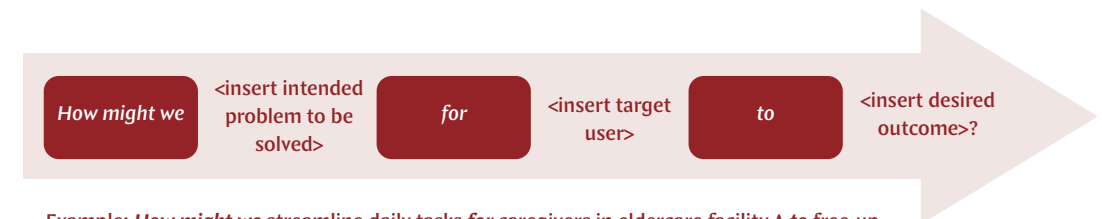
For instance, facilitators challenged the feasibility and practicality of students' ideas. Upon listening to a team's idea of creating a virtual reality prototype customised for individualised physical therapy for the elderly, a facilitator highlighted that virtual-reality tools may not be suitable for senior members of the community, as they may experience motion sickness and discomfort, and may be hesitant to embrace new technology. This design ensured that while the idea and thought process was entirely student-driven, the final output was grounded in practical, human-centric engineering. In addition, facilitators were not assigned to specific tables.

Pedagogical considerations

As teams were not assigned a specific facilitator, this enabled students to receive feedback from diverse sources. This ensured that students were exposed to various levels of feedback as the facilitator team consisted of hackathon alumni volunteers, teaching and research fellows, and faculty. This feedback/consultation process is much more reflective of a professional environment.

• Guidance to scope and define the problem and team moderation

When engaging in a STEM problem for the first time, students may need guidance to scope and define the problem and articulate it clearly and concisely. You may wish to provide a problem statement template to scaffold the problematising process.



Example: *How might we* streamline daily tasks *for* caregivers in eldercare facility A *to* free-up time to focus on high-value tasks for direct patient care and improve job satisfaction?

• Adapting to student profiles and encouraging student-led learning

When engaging in a STEM problem for the first time, students may need guidance to scope and define the problem and articulate it clearly and concisely. You may wish to provide a problem statement template to scaffold the problematising process.

STUDENT EXAMPLE

Nanocare Capsule — A Showering and Drying Capsule for the Elderly

Led by a Biochemistry major Jia Yang who had recently learnt about nanotechnology, this team centred their STEM solution on creating a single enclosed washing and drying system for the elderly. The solution was proposed to reduce fall risk, preserve the dignity and independence of the elderly, and significantly offload the physical demands placed on healthcare workers or caregivers. The key feature in the capsule's design is the use of nanotechnology in various areas, such as the capsule coating (i.e., antimicrobial surface), filtration system (i.e., smart membranes), and in enhancing water efficiency (e.g., nanosensors to detect location).

a. Introduction to Nanotechnology (Scaffolding)

As his team members were unfamiliar with nanotechnology, Jia Yang appealed to them by demystifying “nano-scale”, and shared its common uses in daily life, such as in healthcare, water treatment, and consumer products. They are called nanotechnology because they function at a scale not visible to the naked eye. At that scale, materials behave differently. For example, water does not spread the same way, bacteria cannot cling to surfaces as easily, and surfaces can be designed to repel dirt and kill microbes on contact. When bringing the team up to speed on the basics of nanotechnology, Jia Yang was conscious not to overwhelm them with theory, but to get them comfortable with the idea that nanotechnology is usable, realistic, justifiable, and scientifically grounded.

Some recall of Grades 9 and 10 scientific concepts such as nanoscale, properties of materials (i.e., ability to repel water), and filtration was required.

To ensure everyone was aligned with the basics of nanotechnology and its applications, the team intentionally avoided sourcing technical journal papers in their research. Instead, they relied on information from articles, case studies, brochures, infographics, and websites of national science agencies, university research centres, and government-linked health and research organisations. This helped the team reach a collective understanding of the underpinnings of how nanotechnology works in plain language, with a focus on its application.

Other topics relevant to the Nanocare Capsule design that were explored by the team included:

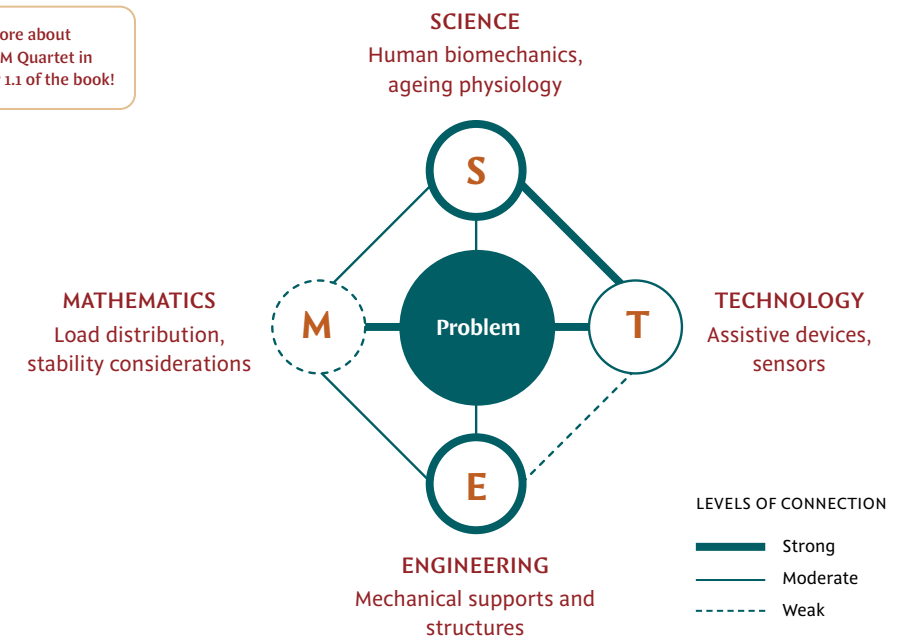
- AI-powered algorithms and machine learning for customisable functions and operational efficiency
- Safety measures, load and stability considerations, and practical design considerations for the capsule
- User comfort, thermoregulation, and ergonomic accessibility
- Water flow, pressure, and waste removal

b. Ideating with the STEM Quartet

After gaining an understanding of the challenges of eldercare in Singapore, the team focused on designing a solution for healthcare workers to relieve the strain on the eldercare ecosystem. Early ideas included assistive transfer tools, smart beds, and mobility aids.

Having previously engaged in a STEM module, students were familiar with the STEM Quartet and decided to map the needs of the healthcare workers to each discipline.

Read more about the STEM Quartet in chapter 1.1 of the book!



Initial STEM Quartet: Mapping broader ideas

Lesson resources

Some of the resources that the team referenced for the project include:



World Health Organization. (2020). *Water, sanitation, hygiene and waste management for COVID-19*



United States Environmental Protection Agency. (2022). *Nanotechnology applications.*



National Nanotechnology Initiative. (2023). *What is nanotechnology?*



7 Amazing Everyday Examples of Nanotechnology in Action — Bernard Marr/Forbes



Sci-Napse committee member Isaiah facilitating a team of students during the ideation process

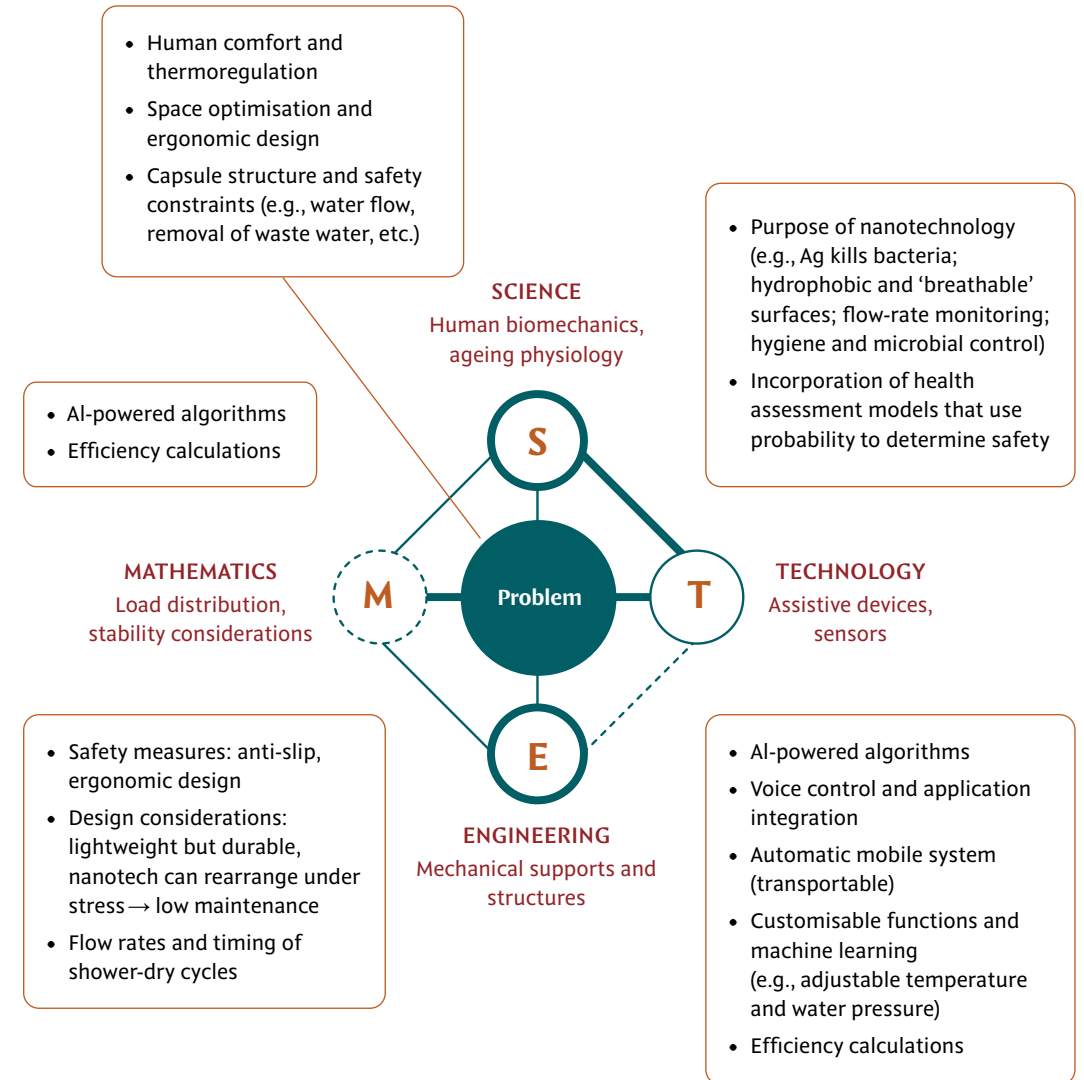
As the ideation process continued, the team noticed a gradual shift in their focus, with a natural gravitation towards addressing the elderly's basic daily needs, which in turn would reduce healthcare worker or caregiver workload. When reflecting on the daily needs of elders, showering emerged as a primary point of concern given its high fall risk, the need for multiple transfers or movement to and from the washroom, and close physical handling when bathed. The team then reframed the problem addressed from “How do we help caregivers move elders?” to “How do we reduce the need for movement altogether?”

c. Finalisation of the Nanocare Capsule concept

Students were not required to physically prototype their solution. Instead, they elaborated on the concepts and rationale of their solution, with the STEM Quartet as the final deliverable. The framework provided students with an opportunity to visually represent the connections shared between the different STEM disciplines and explain how they collectively contributed to the solution's design.

Over the course of the brainstorming and prototyping phase, the team progressively built on their STEM Quartet as the framework for modelling their ideas. The team chose to focus on developing their STEM solution as a virtual prototype, and developed their ideas based on three key criteria:

1. Each design choice had to satisfy at least two STEM domains.
2. Trade-offs (e.g., size vs comfort, cost vs durability) had to be openly discussed and collectively agreed upon.
3. Nanotechnology should be featured as an enabler, not the centerpiece: These criteria helped the team keep their ideas more grounded in the absence of a physical prototype, identify its strengths and limitations, and propose future considerations.



Final STEM Quartet: Identifying core components and considerations in the solution design

Strengths	Limitations	Further considerations
<ul style="list-style-type: none"> • Addresses manpower issues • Personalised and aligned care (independence) • Comprehensive safety • Ergonomical design 	<ul style="list-style-type: none"> • User tech familiarity • Not very widely accessible (cost \$) 	<ul style="list-style-type: none"> • Calibration of sensors • Position of elderly • What medical conditions prevent elderly from using this?

Using the butcher paper and markers provided, students noted down the strengths and limitations of and further design considerations for their STEM solution.

In preparation for their elevator pitch, students narrowed their focus on the merits of their solution to address two areas: **manpower optimisation** and **enhanced quality of life for the elderly**.

- a. **Efficiency and physical relief for healthcare workers:** Traditional methods of showering require an average of 30 to 60 minutes per patient. By deploying multiple individual capsules separated by privacy panels, concurrent showering cycles can occur. This reduces the patient's waiting time as it automates the labour-intensive task of showering and drying a patient. In addition, this enables healthcare workers to prioritise other patients, such as those with complex wound care needs.
- b. **Personalised care and safety:** The capsule utilises nanotechnology to enable precise customisation, adjusting for body shape, height, and user preferences via voice control. Parameters such as water jet trajectory, pressure, and temperature can be customised to meet individual needs. To ensure clinical safety, the design also integrates ergonomic supports and anti-slip surfaces to provide a more secure and comfortable experience.

1. Problematising

Demonstrate understanding of the problem and identify the specific requirements to solve it

2. Proof of concept/prototype pitch

Demonstrate technical viability, intuitiveness of the interface, solution inclusivity, real-world implementation potential

Expected deliverables for the judging process

3. Question & answer segment by panel of judges and participants

Logical and coherent flow of answers supported by sound STEM knowledge and evidence-based research findings

4. Guided reflection by student committee

Students reflect on their communication, collaboration, and information skills

Expected STEM hackathon deliverables

Lesson 4
Team presentation and Q&A segment (15 mins per team for 1.5h), and facilitated reflection (30 mins)

Each team was given 10 minutes to demonstrate their understanding of the problem, the content knowledge, resources, and skills required to solve it and pitch their solution. This was followed by a 5-minute question and answer session which was open to both judges and all student teachers.

The judging team comprised of faculty and research staff from the Natural Sciences and Science Education academic group at the National Institute of Education. The panel offered multidisciplinary expertise in Biology, Chemistry, Physics, Design and Technology, and STEM education.

To promote the practice of teacher reflection, concurrent team reflections were guided by members of the student committee. Students were prompted to evaluate how effectively they communicated and collaborated as individuals and as a team and evaluate their ethical practices. Example questions such as, **“How did your team ensure that each member's voice was heard and their ideas respected?”** and **“Did you encounter any disagreements and how did you overcome them?”** were posed.



Students presenting conceptual solutions using various formats, with (left) and without physical prototypes (top)

Lesson 5
Closing remarks and
award ceremony
(30 minutes)

Judges consolidated their scores and winning teams were decided during the students' reflection. Feedback such as students' innovativeness, creativity, practicality, and potential for implementation were discussed and shared during the closing remarks. The hackathon concluded with an award ceremony. Judges announced and shared their rationale behind the chosen winning teams. Three prizes ranging in voucher amounts from smallest to largest were presented to three winning teams.



A/P Tan Aik-Ling, core member of meriSTEM@NIE, delivering the judges' consolidated feedback and the closing remarks

Given that the STEM hackathon is a joint collaboration between meriSTEM@NIE and the student-led committee Club Sci-Napse, students' solutions were assessed at two distinct levels. This collaborative structure empowers student agency by entrusting the committee members with a key role in both facilitation and assessment processes, while concurrently developing the reflective practices of the student participants.

meriSTEM@NIE judges' criteria

1. Students' understanding of the problem and the STEM knowledge and skills required for their proposed solution
2. Solution design

Club Sci-Napse organising committee's criteria

1. Students' communication and collaborative skills
2. Exercising responsible participation



SCAN TO ACCESS
The detailed
judging criteria



Student voice

“Initially, I viewed STEM as merely the integration of Science, Technology, Engineering, and Mathematics to solve problems. However, through my experiences, first as a participant three years ago and later as a facilitator, I came to realise that STEM is far more than that. It is a mindset, one that instils in us the belief that everyone has the power to create. STEM education empowers students and teachers alike to move beyond theoretical knowledge, transforming ideas into tangible solutions that can make a real impact.

This experience has transformed my teaching practices significantly. I now place greater emphasis on inquiry-based learning and student-led exploration, providing my students with opportunities to tinker, test, and iterate their ideas. I have also been inspired to pilot a STEM-based alternative assessment in my future school as a substitute for subject-specific weighted assessments. I believe that cross-disciplinary learning through their involvement in a large-scale project will provide students with a holistic experience that will help them appreciate the relevance of what they are learning and doing in school through an integrated perspective.”

Isaiah Leong

Student voice

“My participation in the hackathon gave me the courage to adopt a more inquiry-based approach in my teaching, focusing on guiding students to discover rather than simply imparting knowledge. For instance, I recently designed an oil spill workshop where students had to draw on their understanding of properties of oil and different materials to evaluate various oil spill cleaning strategies. This hands-on, cross-disciplinary experience empowered them to see how classroom learning can help them to better understand real world situations.



As a prior participant and facilitator, I am inspired to conduct a hackathon for my students in the future. I believe that the hackathon’s emphasis on discussion and ideation this year, is a wonderful starting and focal point for students who are beginners in STEM. As students become more seasoned with scientific knowledge and practices, they can be encouraged to stretch their potential to build a prototype for their ideas and more.”

Ng Yu Heng

iii. Challenges and solutions in lesson implementation

Potential challenge	Suggested solution
Students often form teams based on existing friendships, leading to a lack of disciplinary diversity for hackathons conducted at the undergraduate level. This can result in solutions that are heavily skewed towards a single STEM field, limiting the solution’s overall scope and innovation.	Pre-assign students to interdisciplinary teams to foster more diverse ideas and innovative solutions.
Unequal contributions among team members can lead to friction and hinder effective collaboration.	Encourage teams to clearly define roles and set expectations for each role to ensure a more balanced and productive collaboration.
In technology-focused hackathons, students may encounter difficulties in rapidly acquiring and applying new coding skills.	Provide expert mentors who can offer targeted, on-site guidance to help students overcome knowledge gaps.



Author’s reflections

Maintaining student engagement in STEM hackathons can be challenging. To augment student participation, consider introducing a team-based evaluation system with student-suggested rewards and establish realistic, time-sensitive, achievable milestones. This promotes individual involvement and a shared sense of accountability.

Furthermore, limiting the quantity of items and promoting the use of recycled supplies highlights the importance of sustainable practices and adds a layer of healthy competition.

Lastly, as the production of a physical prototype or proof-of-concept was not a requirement in this hackathon, the 3-minute elevator pitch served as a key platform for teams to articulate the conceptual framework of their virtual prototype. This required students to translate technical specifications and design rationale into a clear and concise narrative to help judges visualise the user interfaces and the underlying mechanisms. As future educators, this exercise can help pre-service teachers reflect on and surface potential challenges that their students may face in bridging the gap between having a STEM idea and translating it into practice.

Dr Melissa Neo



SCAN TO READ
More about how to implement
a single-day hackathon for
Grade 9 students



Section 4

Cultivating Civic-Mindedness through STEM

- 4.1 Advocating for a Balanced Diet Through Service Learning
- 4.2 Modelling Arrester Beds for Toll Road Safety
- 4.3 The Seed Hands Project: Saving Biodiversity One Seed at a Time
- 4.4 Repurposing Agricultural Waste to Abate Air Pollution
- 4.5 Designing Tidal Early Warning Systems with Micro:bits

This section presents integrated STEM lessons that frame scientific inquiry as a tool for developing a community-driven mindset. They leverage challenges and solutions that are contextualised to and customised for the region in which the lesson is being conducted.

These lessons demonstrate how STEM integration fosters civic empathy and real-world problem solving. By sharpening students' awareness of local systemic issues, the lessons encourage the application of STEM competencies to address community challenges. Students engage in the design process to improve existing solutions or propose new solutions/prototypes. Through this, they gain a deeper understanding of how STEM proficiency plays a role in informing responsible, impactful citizenship.

When reading this section, consider:

- What are some local challenges or issues that your students might be interested in or can empathise with? How can you encourage students to share stories or experiences related to the issue as a starting point for their scientific curiosity?
- How can you encourage students to examine the STEM problem/challenge from the viewpoints of multiple stakeholders to understand the complexity of a community challenge?
- How can you structure the lesson to empower students to have the agency to create and/or act for a better outcome?

Advocating for a Balanced Diet Through Service Learning

Ms Honeylen Mei Libunao, Ms Julie Ann Santos,
Ms Shella Mae Catalan, & Ms Joy Princena



INSTITUTIONAL PROFILE

De La Salle University Integrated School

LOCATION

Laguna, Philippines

TYPE OF INSTITUTION

Private high school

LESSON DETAILS

NUMBER OF LESSONS

28 lessons
(6 lessons each for English & Science, 16 lessons for ACT phase)

DURATION

60 mins/ lesson

GRADE LEVEL

Grade 8

SUBJECT/ DISCIPLINE

Science, English, Service Learning

NO. OF STUDENTS/ PARTICIPANTS

232

STUDENT READINESS

Mixed to high ability

Having an imbalanced diet can lead to nutrient deficiency. In this chapter, teachers from De La Salle University (DLSU) Integrated School crafted an innovative module that integrated Biology, English, and Data Analysis, to explore the nutritional intake of students and families in two public schools. Through applying concepts of digestive health and evidence-based data interpretation, the project culminated in a service learning project where DLSU Integrated School students designed their own campaign to raise awareness on the importance of a balanced diet and knowledge of the consequences of nutrient deficiency using persuasive speech.

In this chapter, we learn:

- ✓ How to design a STEM module that integrates Biology and English curricula with service learning objectives
- ✓ The foundational concepts of digestion and digestive health in Biology, and analytic report writing in English
- ✓ How qualitative and quantitative research data can be used to model data analysis and visualisation

Each term, De La Salle University (DLSU) Integrated School takes inspiration from different government institutions to develop a theme for the term's service learning project. In 2025, the Grade 8 English and Science project centred on **“Nourish Your Gut, Cultivate Health: A Journey to Prevent Digestive Diseases through Nutrient Wellness”**, a theme crafted by the school team based on initiatives from the Philippine Society of Gastroenterology (PSG). PSG is the nation's leading professional organisation for gastroenterologists. Since 2007, this non-profit organisation has spearheaded Philippine Digestive Health Week (PDHW), an event held annually in the second week of March. PDHW serves as health advocacy platform dedicated to elevating public awareness of promoting digestive wellness.




In line with this theme, students of DLSU Integrated School participated in a service learning project focused on mitigating nutrient deficiency and promoting nutritional wellness in their community. Enacted as part of the school's service learning module (which combines curriculum learning objectives with community service), the project integrated knowledge and core competencies from Science (i.e., nutrition and the digestive system) and English (i.e., persuasive rhetoric). It culminated in a community symposium where students presented original infographics detailing the risks of nutrient deficiency, and delivered persuasive speeches to advocate for and raise awareness on the importance of healthy dietary practices. At the community level, the programme engaged involvement from local public schools, whose students provided survey data on their family's eating habits, and attended the symposium as primary stakeholders.

By combining challenge-based learning (CBL) with the Lasallian Reflection Framework (LRF), the programme encouraged students to engage in critical thinking and social responsibility to produce a tangible, evidence-based health advocacy campaign for the community.

Topics covered in this lesson	
Science (Biology)	English
<ul style="list-style-type: none"> • The digestive system • Nutrient deficiency (diseases and ways to prevent them) 	<ul style="list-style-type: none"> • Persuasive speech • Creating survey questionnaires and articulating data-informed claims • Research report writing
Technology	Mathematics
<ul style="list-style-type: none"> • Using graphs and tables to visualise or map out relationships between concepts and/or information • Using multimedia presentation tools to design presentation posters 	<ul style="list-style-type: none"> • Data analysis for evidence-based claims

Module structure

The programme commenced with consecutive 6-day instructional units in Science and English, designed to establish foundational knowledge. Following this, students applied the acquired content knowledge and competencies through a service learning project, which concluded with a symposium. This flowchart showcases the integration of CBL with the LRF mapped to the topics and activities from the core disciplines of Science and English.



DAY 1 | See - Experience


ENGAGE
(Introduction to the big idea, essential question, and challenge)

Students are guided to formulate guiding questions that frame their investigations.


DAYS 2-6 | Analysis - Reflection

INVESTIGATE
(Student-centered and inquiry-based activities)

SCIENCE: laboratory activity, group reports, reflection
ENGLISH: data analysis, generating graphic organisers, persuasive speech skills



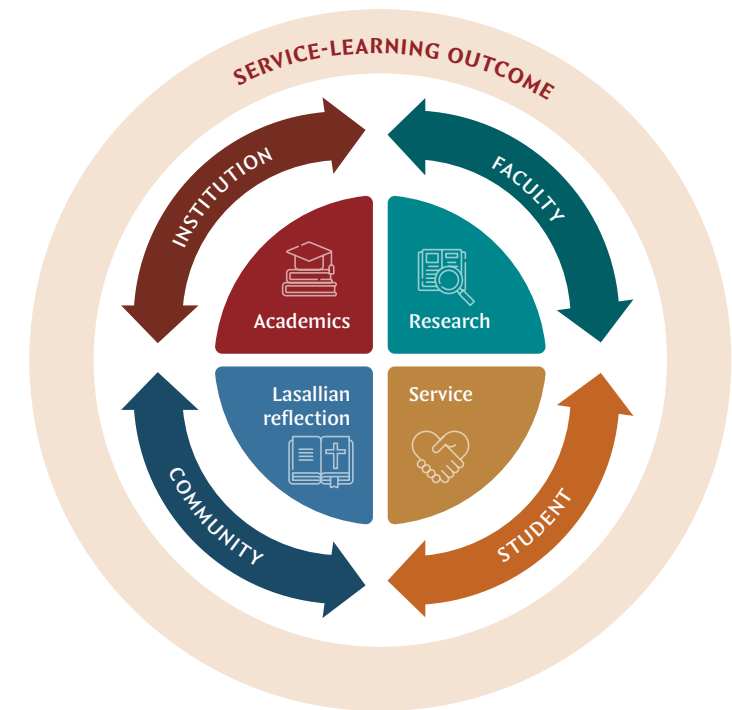
2



DAYS 7-14 | Commitment - Action

ACT
(Students' solution in response to challenge)

Grade 8 students conducted a symposium for Grade 7 students and their parents from nearby public schools on digestive health.



The Service Learning Framework

Aligned with DLSU's mission of social transformation, the programme was designed to uphold the values and core principles of the service learning framework.

The service learning framework is guided by principles of reciprocity and reflective practice. Adapted from Robert Sigmon's 1994¹ seminal work on service learning, the principle of reciprocity reflects equal weighting for both service and learning goals and mutual enhancement. Students "serve to learn" and "learn to serve". On the other hand, the principle of reflective practice serves as the bridge between service experience and academic content through intentional retrospective reflection to shape and drive future practice. As such, the programme integrated excellence in teaching with evidence-based community development, prioritising regional collaboration and innovation to drive social impact and/or change.

Integration of challenge-based learning and the Lasallian Reflection Framework for this integrated service learning project

1. Sigmon, R. L. (1994). *Linking service with learning*. Washington, DC: Council of Independent Colleges.

Module alignment and integration

Prior to the start of each term, teachers from each grade level convene for a Project Integration meeting. During these meetings, teachers discuss subject-specific learning outcomes, goals, and core competencies that students must demonstrate upon module completion. Teachers then brainstorm and design the term's lesson plans with the primary objective of creating strategic cross-disciplinary learning experiences.



The integrated lessons are intentionally designed to ensure that students:

1. Create more authentic contextualised project/ lesson outputs
2. Apply cross-disciplinary concepts and skills to enhance long-term knowledge retention
3. Recognise disciplinary connections and develop a more comprehensive understanding of the topics
4. Cultivate 21st-century skills, specifically communication, creativity, collaboration, and critical thinking

The planning process can be summarised as follows:

1. **Alignment:** Teachers first identify a core project output that can effectively accommodate the integration of competencies from various disciplines.
2. **Module Design and Scaffolding:** With the core output in mind, teachers then design scaffolded activities, instructional lessons, and assessments for each of the subjects required for students to successfully complete their final integrated project. For project outputs that can add value to the community, the module structure is adjusted to align with the phases of the service learning framework.
3. **Schedule Management (Timetabling):** To ensure that the topics and scaffolded activities are delivered in a logical, cohesive sequence, lessons for each subject must be synchronised and delivered in a timely manner. For the project featured in this chapter, one Science and one English lesson each week were dedicated to their service learning project.
4. **Assessment:** A collective marking rubric is developed with subject-specific criteria. Each subject's teacher defines the parameters for their respective discipline, to ensure a targeted approach for the components that they are responsible for evaluating.




The 2025 service learning programme was built on the overarching goal of leveraging students' knowledge on nutrient deficiencies to construct evidence-based persuasive speeches that promote healthy lifestyle practices. The programme provides a meaningful opportunity for scientific data and research to be transformed into an avenue for social advocacy to address real community needs, while cultivating technical literacy and skills for purposeful, persuasive communication.






Module plan

Designing a campaign for balanced nutritional intake

i. Desired learning outcomes and objectives

Learning outcome	Rationale
 <ol style="list-style-type: none"> 1. Explain ingestion, absorption, assimilation, and excretion 	<p>Inquiry-based learning</p> <p>Students reflect on personal experiences. For example, a student may be asked to eat a snack and articulate how the parts of the digestive system break it down. Opportunities to ask questions are given to invite students to think more deeply and surface their ideas and understanding of digestion.</p>
 <ol style="list-style-type: none"> 2. Compare the frog's digestive structures with the human digestive system 	<p>Hands-on and multimodal instruction</p> <p>Combined with lecture-based lessons, hands-on activities such as frog dissection cater to various learning styles (visual, kinaesthetic, auditory) and nurture scientific skills and competencies such as technical dexterity and precision and empirical observation.</p>
 <ol style="list-style-type: none"> 3. Describe the role of the digestive structures in the digestive process 	<p>Activating prior knowledge</p> <p>Prompting questions or sentence starters can help trigger recall and in turn gauge students' prior knowledge.</p>

Learning outcome	Rationale
 <p>4. Explain how diseases of the digestive system are prevented, detected, and treated</p>	<p>Problem-based learning</p> <p>The project is centred on a problem in which students must propose evidence-based explanations or solutions. Students acquire content knowledge on diseases of the digestive system through the research they conduct.</p>
 <p>5. Analyse and present data gathered on diseases resulting from nutrient deficiency using graphs and tables</p>	<p>Evidence-based argumentation</p> <p>Students analyse community-based data, make evidence-based inferences and present their reasoning in visually and verbally persuasive ways.</p>
 <p>6. Deliver a speech to persuade students and parents to make healthy choices about their food intake to prevent nutrient-deficiency related diseases</p>	<p>Design thinking</p> <p>Students learn to empathise and consider the needs, perspectives, and challenges of members of their community regarding food choices and nutrition. They define the communication goal of their speech based on data-informed evidence. They brainstorm strategies and persuasive techniques that they can use to refine their speeches after receiving feedback.</p>

Expected deliverables from the students by the end of the activities

- Visually represent a summary of the data collected from public school Grade 7 students and their parents using a graphic organiser
- Compose an expository and persuasive text (i.e., campaign) that raises awareness on the importance of nutritional quality and dietary interventions that prevent risk of nutrient-related diseases
- Present their campaign at the community symposium. The symposium must capture the audience's attention; be supported by strong evidence (credible information, data, and insights) on food-related diseases and prevention; and inspire the audience to take action to improve their nutritional health



ii. Carrying out the module

This programme integrated knowledge from Science (Biology), English, and service learning. The Science and English lessons followed the same six-day structure of the Lasallian Reflection Framework, moving from Engage to Investigate. The module concluded with the service learning project, where students applied their knowledge, collated and analysed data from the community, and built their own health advocacy campaign.

Science

Six days were dedicated to covering content on digestive health to fulfil core curriculum requirements.

SCIENCE

Day 1
Engage phase
(60 mins)

During the Engage phase, a big idea was first presented to the students. The teacher then posed essential questions and tasked students with a challenge. The essential question helped prompt students to reflect on their knowledge base, identify gaps in their knowledge, and formulate questions for further clarification and research as they navigate the challenge given.

<p>BIG IDEA: Digestive health</p>	<p>ESSENTIAL QUESTION: What are the practices that help Filipino families prevent the risk of nutrient-deficiency diseases?</p>	<p>CHALLENGE: Promote awareness about digestive health among Filipino families</p>
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SCIENCE

Days 2–6
Investigate phase
(60 mins per day)

In the Investigate phase, students actively explored the guiding questions provided by engaging in a series of student-centred, inquiry-based activities. These experiences allowed them to continue building their foundational knowledge on the digestive system and nutrition through observation, research, analysis, and reflection.

GUIDING QUESTIONS:

- What are the organs, characteristics, processes, and enzymes involved in human digestion?
- How do animals differ in ingesting food?
- Where does each digestive process start and end?
- What is nutrient deficiency?
- What are the causes and effects of nutrient deficiencies in humans?
- What healthy lifestyle/practices should everyone follow to take care of their digestive health?



Activity 1: Think-pair-share

Using the think-pair-share strategy, students discussed:

- How animals such as baleen whales and frogs differ in ingesting food compared with humans
- Observations and prior knowledge on how the body digests specific parts of a burger when eaten

From this activity, students learnt how different digestive organs in different animals serve unique functions that cater to their diet and environment. Through studying a relatable activity like eating a burger, students learnt how macronutrients (carbohydrates, proteins, and fats) are digested in the body.

Activity 2: Frog dissection (Lab activity)



The aim of this activity was to provide students with a comparative anatomical learning experience, to build familiarity with and emphasise differences between the digestive systems of animals (i.e., frog) and humans. By comparing and correlating the physical dissected frog specimen with textual content, students developed a more robust understanding of the digestive system.

Prior to the laboratory session, students used Froguts (an online simulation) to establish foundational knowledge on the anatomical structures of a frog. The simulation allowed them to explore the dissection process in a low-pressure virtual environment, fostering procedural familiarity and technical confidence to carry out the subsequent hands-on dissection.

During the lab activity, they were tasked with the following steps:

- a. Touch and describe the structure of each digestive organ and the digestive tract in the frog
- b. Answer the analysis section in the report sheet

Pedagogical considerations

- Hands-on activities such as the frog dissection provide a critical opportunity for students to observe firsthand the morphological parallels between the human and amphibian digestive systems. This moves learners beyond theoretical models to develop a more profound, informed, 3-dimensional understanding of the digestive system.
- Using a simulation prior to actual hands-on activities is a good way to scaffold students' learning and build their confidence and technical experience in the laboratory.




Activity 3: Group report

In this activity, students took on the role of “nutrient detectives”. The class was divided into five groups.


Each group was assigned a specific vitamin or mineral, and tasked with:

1. Investigating its function in the body, common food sources, and diseases associated with its deficiency
2. Sharing their findings with the class in a 5-minute presentation



Research your assigned nutrient and prepare a short report or presentation that includes the following:

- Name of the Vitamin or Mineral (e.g., Vitamin A, Iron, Calcium, etc.)
- Function in the Body
 - What does this nutrient do? Why is it important?
- Food Sources
 - What foods are rich in this nutrient?
- Deficiency Effects
 - What happens if a person doesn't get enough of this nutrient? Name the disease(s) or symptoms caused by the deficiency.



The Nutrient Detectives Task



Activity 4: Reflection

To conclude the Investigate phase, students engaged in a reflective activity that allowed them to internalise the significance of proper nutrition not just as a scientific concept, but as a personal and social responsibility. Students were asked to reflect on the following statement:

“Proper nutrition is essential for maintaining a healthy body, as vitamins and minerals play a crucial role in growth, immunity, and overall well-being. By ensuring a balanced diet rich in essential nutrients, we can prevent deficiency diseases, support bodily functions, and enhance our quality of life. As a Lasallian, what do you think is your role in promoting proper nutrition to your peers and your family members at home?”

The reflection activity was carried out as a guided class discussion, and students were asked to verbally share their thoughts with the class. Most students shared that maintaining a balanced diet, checking the nutrition facts of available food at home, and limiting the consumption of junk or instant food were ways they practise healthy eating. Some students also mentioned that certain family members follow specific diet plans, particularly those with conditions such as diabetes.

Pedagogical considerations

- Collaborative research is an engaging way to encourage peer learning and deepen students' content mastery, while reinforcing real-world relevance (i.e., of good digestive health).
- The reflection activity supports the complementary nature of how scientific knowledge informs our daily practices and values-formation, and empowers students to take meaningful action grounded in service to the community.

English

The English curriculum comprised lessons focused on debate and the use of persuasive language.

Survey preparation

As part of the school's and programme's community outreach, the school's social action office identified two public schools within the community that were willing to participate in the service learning project. Surveys were then distributed to the Grade 7 public school students. The survey focused on the dietary intake and eating habits of these students and their parents, and the data was collected and analysed by the DLSU Integrated School students in the following lessons.

ENGLISH

Day 1
Engage phase
(60 mins)

The lesson began with a virtual class debate on the topic "Smoking should be banned in the country." Students were divided into "Pro" and "Con" groups, given 10 minutes for discussion in breakout rooms, and then presented their points.

After the debate, the class discussed a research report which presented findings from 1990 to 2017 on lung cancer and its risk factors.

The session concluded with a reflection on the impact of lifestyle choices on one's health and well-being. The reflection task aimed to help students recognise the correlation between individual lifestyle choices or behaviours with broader systemic health outcomes. It bridged the gap between personal well-being commitments and the collective public health burden.



SCAN TO ACCESS

The research article "Global, Regional, and National Burden of Lung Cancer and Its Attributable Risk Factors, 1990 to 2017"

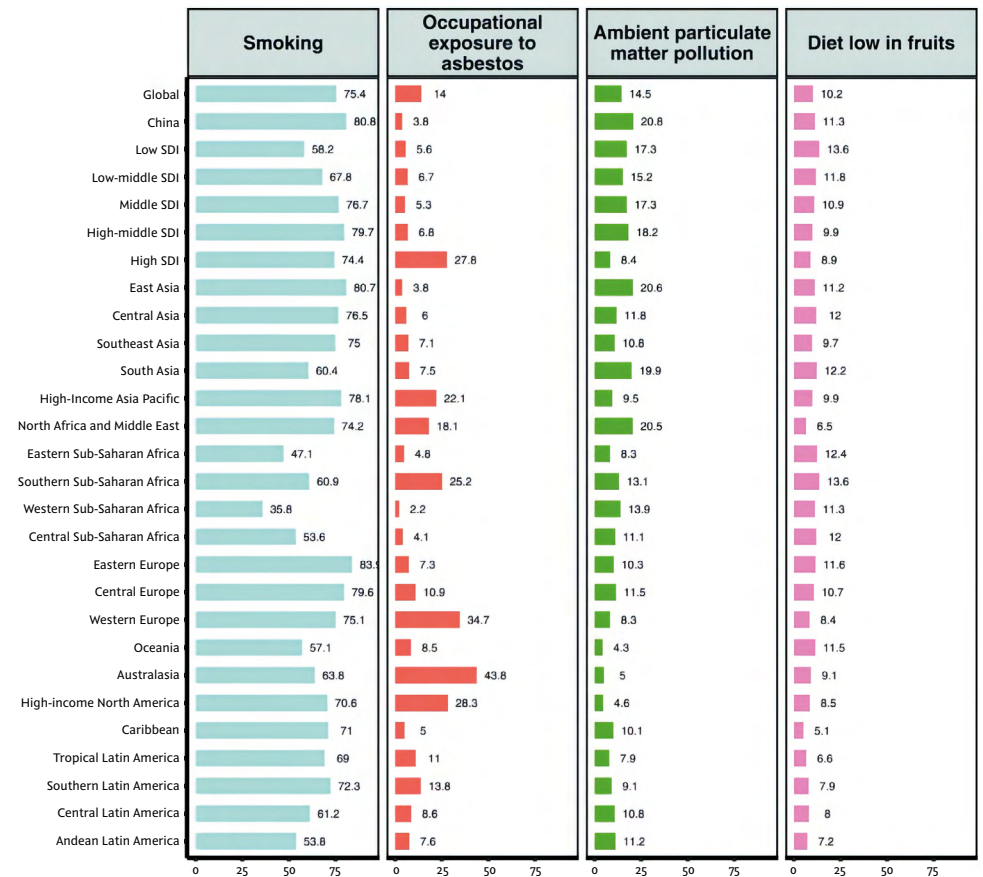


ENGLISH

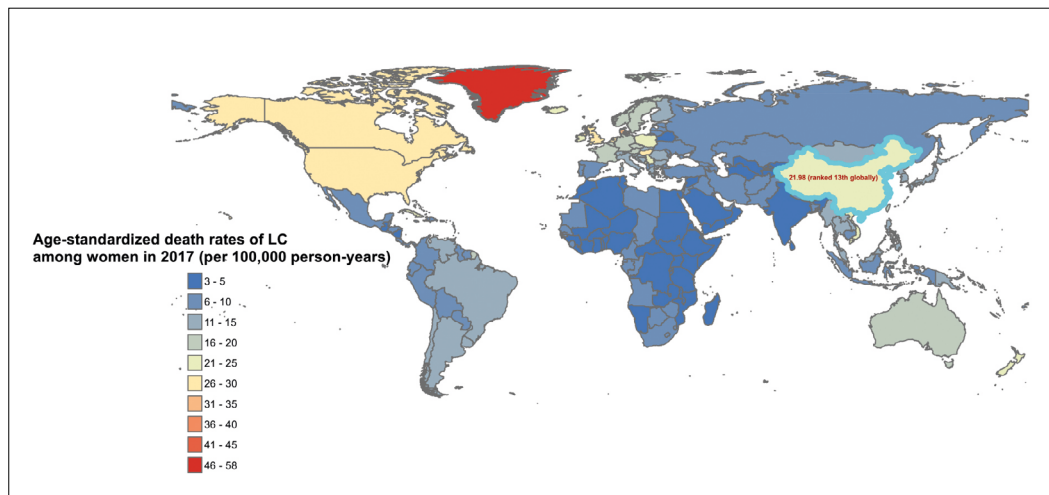
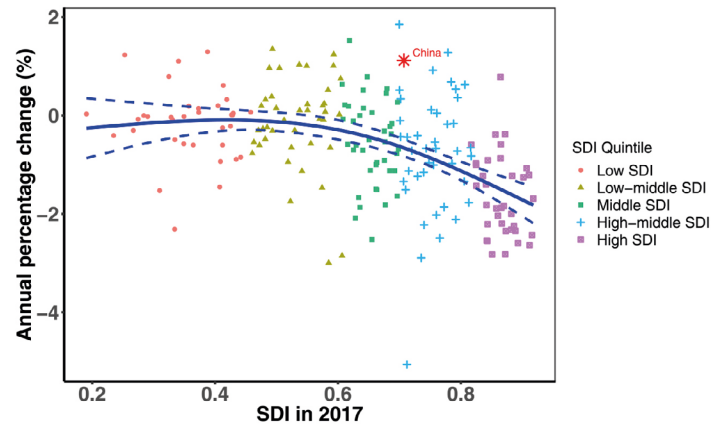
Day 2-6
Investigate phase
(300 mins)

Activity 1: Analysing graphs and tables

In this activity, students continued the analysis of the research report by closely examining the graphs and tables used by the authors. They identified the types, purposes, and effectiveness of the visuals used. They also examined the structure, language, and intent of the included text.



Examples of different graph and table types in the research report



Examples of different graph and table types in the research report

The activity required the class to answer the following questions:

- What are the graphs and tables found in the research report? What are these for?
- How do these help in showing essential information?
- Describe the purpose, language, and parts of the research report.

In addition, the activity enabled the teacher to segue into an introduction on expository writing, graphs and tables, and the presentation of a related task (i.e., creating a survey report).

Activity 2: Creating a survey report

The students were given sample survey data for this activity. The sample data was modelled after data collected from two public schools in the community. The questions revolved around what Grade 7 students and their parents usually eat, how they prepare their meals, their health habits, and any digestive problems they have experienced.

Students were tasked to organise the data and write a summary on the essential takeaways inferred. The survey report had to include:

- An introduction on the background and goals of the survey
- Different types of graphs and tables used to present the key survey results
- A conclusion that summarises the key points and insights from the survey

Students were guided to create their graphs and tables using Canva, with tips on how to effectively organise their data and present the survey results. The content of their survey report had to include:

- A description of the digestive processes (ingestion, assimilation, digestion, and excretion)
- What a healthy diet entails
- Common nutrient deficiencies
- An analysis report (based on the collected data)
- Digestive health tips
- References

Did you know?

The public schools were selected by the Integrated School's social action office. This office is responsible for all of the institution's community engagement efforts. At the beginning of each school year, the office meets with the academic team to plan the school's service learning initiatives. The academic team shares integrated projects that could be extended to the service learning module while the office suggests communities that could benefit from student outputs.

In this project, the office suggested two public schools in the area whose schedules could accommodate the project's timeline. The Grade 8 English and Science teachers, along with representatives from the social action office, met with the schools' principals to brief them on the project's objectives, activities, timelines, and requirements.

Activity 3: Data analysis of survey findings

In this activity, real data collected from Grade 7 students and their parents from two public schools were used. Three survey types were administered to the public school communities:

TO THE
CANTEEN
STAFF:

to understand
the meals
prepared in
schools

TO THE
PARENTS
OF GRADE 7
STUDENTS:

to understand the
meals prepared at
home

TO THE
GRADE 7
STUDENTS:

to understand their
food intake, habits,
dietary options, and
preferences

Survey Questionnaire - FOOD PREPARED IN SCHOOL

A. DIRECTIONS: Answer the following questions by putting a check mark (✓) in the box/column. Please answer the question honestly. Do not leave each item unanswered.

1. What is the weekly frequency for the following food categories served in your school? Please refer to the rating scale below.

Scale:

- Never 0
- Very rarely 1
- Occasionally 2
- Quite often 3
- Very often 4

Food Categories	0	1	2	3	4
Meat					
Vegetables					
Fruit					
Dairy Specify: _____					
Sweets Specify: _____					
Rice, Bread					
Others: Specify: _____					

2. How important are each of the following characteristics to you when selecting foods to prepare for your school? Please refer to the rating scale below.

Scale:

- Unimportant 1
- Important 2
- Very important 3

Food Characteristics	1	2	3
Low price			
Good flavor			
Healthy food			
Nice packaging			
Others: Specify: _____			

3. Is the information on the student's body mass index (BMI) accessible in your school?
 Yes No I don't know

Sample section of survey given to canteen staff

Survey Questionnaire - PARENTS

Background:

This survey will help you realize the contents of your child's food diet. Fruits and vegetables provide a variety of different vitamins and minerals as well as being a good source of fiber. Eating at least 5 portions of these a day will contribute towards reducing the risk of digestive diseases.

Ang palatanungan na ito ay makakatulong upang maisip natin ang mga nilalaman ng diyeta ng mga anak natin sa pagkain. Ang mga prutas at gulay ay nagbibigay ng iba't ibang iba't ibang bitamina at mineral pati na rin ang pagiging isang mahusay na mapagkukunan ng fiber. Ang pagkain ng hindi bababa sa 5 bahagi ng mga ito sa isang araw ay makakatulong sa pagbabawas ng panganib ng mga sakit sa na may kinalaman sa sistemang digestive.

Name of Child/Pangalan ng Anak (optional): _____

Age of Child/Edad ng Anak: _____

Grade level & Section of Child/Baitang at Pangkat ng Anak: _____

Weight of Child/Timbang ng Anak: _____

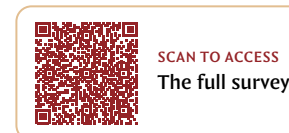
Height of Child/Laki ng Anak: _____

A. DIRECTIONS: Answer the following questions by putting a check mark (✓) in the box/column. Please answer the question honestly. Do not leave each item unanswered.

PANUTO: Sagutan ang mga sumusunod na tanong sa pamamagitan ng paglalagay ng tsek (✓) sa kahon/kolum. Huwag iwanang walang sagot ang bawat aytem.

- How many meals does your child usually eat per day?
(Ilang beses kumakain sa isang araw ang iyong anak?)
 1 2 3 4+
- What meal would you consider to be the main meal of your child for the day?
(Anong pagkain ang ituturing mong pangunahing pagkain ng iyong anak sa isang araw?)
 Breakfast/ Agahan
 Lunch/ Tanghalian
 Dinner/ Hapunan
 Snacks/ Meryenda
 Others/Iba pa: Specify/Pakilagay: _____
- What does your child's main meal consist of?
(Ano ang bumubuo sa pangunahing pagkain ng iyong anak?)
 Meat/Karne
 Fruits/Prutas
 Vegetables/Gulay
 Rice/Kanin
 Others/Iba pa: Specify/Pakilagay: _____

Sample section of survey given to parents



Students used Google Sheets to conduct quantitative and qualitative data analysis, with a focus on frequency distribution and descriptive synthesis (such as identifying common themes/ideas and summarising key points).

The data analysis process required students to:

- ☑ Use tables, graphs, and infographics or maps to represent key survey findings
- ☑ Explain the visual-verbal relationships between expository text and data illustrated in tables, graphs, and information maps

FINDINGS

Typically, raw data is truly complex to comprehend as the amount of data given may appear overwhelming due to the extensive amount of text and the cluttered format. Therefore, the researchers decided to utilize or create graphic organizers, specifically bar graphs. Utilizing the supplied raw data, the researchers were capable of formulating graphic organizers to generate a vivid or clear visual representation. Briefly, bar graphs are operated to compare or analogize the different sets of data. Subsequently, below are the created bar graphs from the given data acquired from the conducted survey.

Here, in Figure 1, you can see that 21 students, or around 70% of them have 3 meals a day, with only 7 having 4 or more meals. Fortunately, only 2 students consume 2 meals a day. The majority of students presumably consume 3 meals a day since their budget is qualified to provide for their family; however, pupils who have 2 meals a day may be a consequence of the ineptitude to purchase food owing to the fact that the Philippines is a relatively poverty-stricken locale.

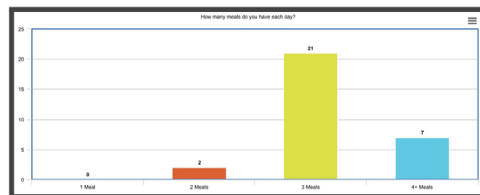
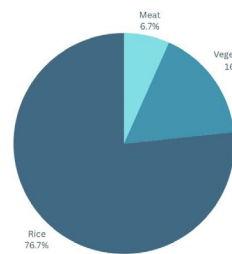


Figure 1. The number of meals the learners intake in a day.

Q3: What does your child's main meal consist of?



People create delicious meals consisting mainly of greens, carbs, and protein to keep themselves and their family healthy. But while they use all or most of these ingredients, they tend to have their focus on a certain food when cooking. From the respondents' answers, the majority of the respondents (76.7%) say that rice is the main meal of their child, 16.7% say it is vegetables, 6.7% say that meat is the main meal of their child, and 0% or none of the respondents say that fruits are the main meal of their child.

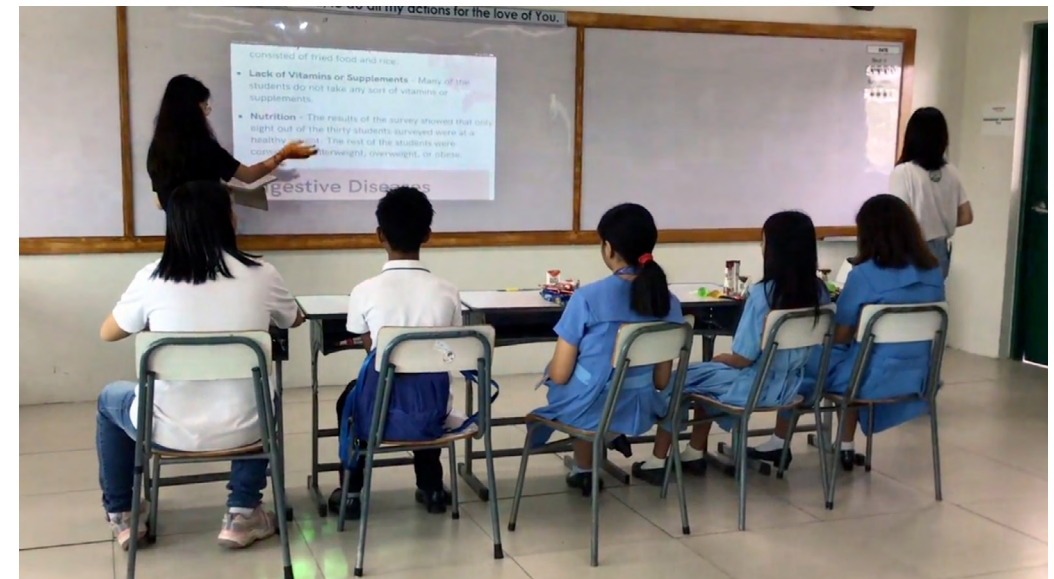
Examples of students' survey analysis

Given that data was collected from authentic respondents, the primary challenge involved ensuring data completeness and achieving a viable sample size that was representative of the community. Students also experienced issues with verifying data reliability, identifying trends in the data, and drawing meaningful evidence-based conclusions, as this was not covered in the main curriculum. To address this, teachers sourced research to model their data analysis and draw evidence-based conclusions accordingly.

By analysing real data from their own surveys, this helped to move students' learning beyond assumptions, opinions, and passive instruction to evidence-based arguments and justification. They learned quantitatively and qualitatively about the health and dietary choices of members of their own community and were able to identify potential gaps in their knowledge or awareness, allowing them to frame their campaigns using data-informed findings.

Pedagogical considerations

- Leveraging authentic socio-scientific issues such as the impact(s) of smoking encourages students to hone their debate skills (e.g., rhetorical strategies) while activating prior knowledge. This contextualised approach can serve as a catalyst for deeper inquiry in the subsequent phases.
- By first having students analyse an exemplar exposition and the use of graphs and tables to effectively convey the key takeaway message, this provides foundational knowledge to support their final project.



Student presenting her findings



Service learning application

Finally, students applied the content knowledge and skills acquired in their Science and English lessons to their service learning project.

Days 7–14: Act

The service learning framework was evident in the Act phase as students designed campaigns for public outreach. The table below details how CBL and service learning were integrated into the final phase of the **Lasallian Reflection Framework**.



1

See - Experience

Students gained insight into the challenges faced by public school students regarding gut health through the collection and analysis of survey responses. While the experience was indirect, it offered a deeper understanding of health-related issues within a broader social context.



2

Analysis - Reflection

Through frog dissection, survey reporting, and data interpretation, students critically examined the causes and implications of nutrient deficiency. This process allowed them to reflect on the scientific, social, and ethical dimensions of the issue, strengthening their sense of responsibility as student-researchers.



3

Commitment - Action

The service learning principles of reciprocity and reflection were evident in the planning and implementation of the community health symposium. Students designed brochures to make their findings accessible, developed multimedia presentations, and campaigned with persuasive speeches. These efforts were made to inform and influence their audience — peers, teachers, and parents — to make healthier dietary choices and prevent nutrient-related diseases.



SERVICE LEARNING

Day 7
Orientation
(60 mins)

Students were introduced to the service learning project using the GRASPS (i.e., Goal, Role, Audience, Situation, Product/Performance, and Standards) framework.

Students were briefed on their task to create a three-minute persuasive speech. They were presented with the speech requirements and evaluation rubric as described below.

PROJECT OVERVIEW

Students act as members of the Philippine Society of Gastroenterology's education committee, tasked with delivering a three-minute persuasive speech in Biñan, Laguna. The audience consists of school children and parents.

SPEECH REQUIREMENTS

The primary goal is to encourage healthy eating habits and prevent diseases caused by nutrient deficiency. The speech must:

- Introduction:** Cover the digestive processes and what a healthy diet entails comprehensively
- Body:** Provide an analysis of survey results
- Conclusion:** Offer actionable lifestyle recommendations

EVALUATION

The project is evaluated based on two sets of criteria:

- English criteria:** Clarity of purpose, use of persuasive elements (e.g., **logos, ethos, and pathos**), and effective non-verbal communication
- Science criteria:** Content accuracy, collaboration, and effective time management



Students were also briefed on an overview of the symposium, including the schedule, expected outputs, safety instructions, and logistics.

SERVICE LEARNING

Day 8–9
Data analysis
(240 mins)

Students used the data analysed from their Science and English classes to better understand the types of food consumed by and health habits of their community members.

Students applied the knowledge gained from close examination of the research article, “Global, Regional, and National Burden of Lung Cancer and Its Attributable Risk Factors, 1990 to 2017” to select and present the key findings in various ways that would appeal to and engage their audience.

SERVICE LEARNING

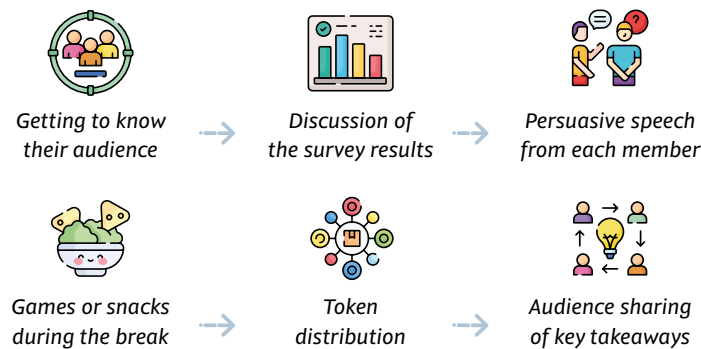
Day 10–13
Symposium preparation
(480 mins)

The English and Science periods were used on days 10 to 13 to prepare for the symposium. Using digital applications or programmes of their choice, students created brochure materials that they disseminated to the community in attendance at the symposium. They also used this time to conduct a dry run of the symposium and rehearse their speeches.

SERVICE LEARNING

Day 14
Symposium
(180 mins)

Each group of students was assigned five members from the symposium as their audience. Concurrent presentations were held during this mini forum. Students were tasked with the following activities:



Beyond disseminating information on nutrient deficiency and digestive health, students advocated for preventative wellness strategies to be implemented to mitigate long-term risks of nutrient deficiencies or related diseases.

At the end of the symposium, students responded to a programme evaluation survey. Student feedback included wanting more time to prepare their final output and rehearse their speeches; more time spent with students from the participating partner schools; and healthier lunches provided during the programme.

Digestive Processes

Ingestion
The process of taking food through the mouth.

Digestion
Breaking down the large particles to smaller ones as it absorbs nutrients.

Absorption & Assimilation
Movement with the digested food molecules into the cells of the body.

Excretion
Occurs when the feces pass out of the body through rectum & anus.

Healthy Food Diet

A healthy diet promotes health, supporting your muscles and bones, boosting your immunity, helping your digestive system, and more. To implement a healthy diet, you will need to include a variety of protein, fiber, carbs, and healthy fats into your plate.

Nutrient Deficiency
Nutrient deficiency is when our body has insufficient supply of vitamins, minerals and nutrients needed for growth and development, as well as to maintain a healthy lifestyle.

Understanding the children's diet

g1. Hunger levels throughout the day. g2. Vitamin intake. g3. How their food is cooked. g4. Their usual meal gap. g5. Their food intake.

FOOD GROUP	MEAT	VEGETABLE	FRUIT	GRAIN	DAIRY	EGG	BEAN/TOFU
protein	5	5	4	3	3	2	
carbohydrate	3	7	13	15	3	2	
vitamin	14	5	11	5	3	3	
minerals	2	3	2	1	7	18	

Diseases from unhealthy habits

Ulcer

- When skipping meals and eating unhealthy food early in the morning.

Chronic Fatigue

- From the drastic changes in the immune system like from not eating that the body responds as an infection or stress.

Slowed Down Metabolism

- Caused mainly by skipping meals. It can lead to weight gain, weakness, and fatigue.

Vitamin C Deficiency

- Occurs when one does not eat enough vegetables or fruits.

Diabetes

- Caused by high processed meats and carbohydrates.

Malnutrition

- Result of a poor diet.

Healthy Tips

Mindful Eating

- Instead of focusing on what you eat, focus on how you eat and the time you consume your meals.

Food Swapping

- Swap your favorite sweets or processed foods for a healthier but still satisfying alternative!

Track Each Meal

- Make sure you're eating a balanced diet with protein, fiber, and carbohydrates.

Take Your Vitamins

- Using supplements can ensure you that you're getting an adequate amount of a specific vitamin.

Be Aware of the Potential Illnesses

- Being aware can give you a sense of control.

Swap Out Bigger Plates to Smaller Ones

- Prevents overeating (can cause obesity).

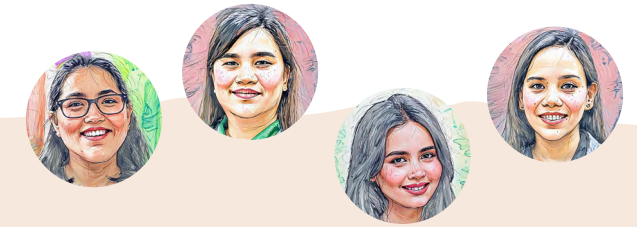
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www.delasallegroup3.com

Sample student brochure

iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
<p>One of the main challenges encountered was the variation in students' prior knowledge of the digestive system. As students came from diverse learning backgrounds, such as traditional classroom settings and homeschooling, their prior understanding and recall of key concepts, like the basic parts and functions of the digestive system (typically covered in grade school), varied significantly. This affected the pace of the lesson and required differentiated strategies to ensure that all students could engage meaningfully with the new content.</p>	<p>Use Self-Paced Supplemental Activities</p> <p>To support equitable participation among the learners, we used additional scaffolding to bridge these gaps. We maximised the use of our learning management system by creating dedicated tabs with self-paced quizzes, curated video lessons, and additional readings. This strategy allowed students to catch up independently on foundational knowledge, while maintaining the overall flow of the lesson for the class.</p>
<p>The survey and reporting phases during the English modules revealed several challenges that became valuable learning opportunities for the students. The biggest challenge was their data literacy skills. Since the data was collected from authentic respondents, there were issues with identifying trends in the data and drawing meaningful conclusions at the community level.</p>	<p>Model Analysis with Sample Data</p> <p>By walking through a sample dataset together and modelling how to find trends, identify outliers, and draw basic conclusions, students can gain an appreciation for how data analysis supports the reporting process.</p>



Authors' reflections

Students' engagement with STEM was elevated when their learning moved beyond traditional instruction to address authentic, community-based challenges. By utilising digital tools for data visualisation and virtual simulation, the students cultivated technical proficiency and communication skills essential for scientific inquiry through a scaffolded approach.

Overall, the programme was designed as an interdisciplinary initiative that positioned the students as active community health educators and bridges between theoretical knowledge and exercising social responsibility through action. Indirect interaction with their local community members through data analysis revealed critical gaps in public health literacy, reinforcing the real-world stakes of their findings and the importance of the symposium.

Beyond discipline-specific competencies, the programme addedly fostered empathy, leadership, and resourceful problem-solving. The challenge of simplifying complex biological concepts for a diverse audience encouraged students to iteratively refine their expositions to prioritise clarity.

Ultimately, by integrating the LRF with CBL and the service learning principles, the programme demonstrated how content mastery and service to the community can empower students to make a tangible difference in the lives of others.

Ms Honeylen Mei Libunao, Ms Julie Ann Santos, Ms Shella Mae Catalan, & Ms Joy Princena

4.2

Modelling Arrester Beds for Toll Road Safety

Ms Dyne Rizki Puspitasari



INSTITUTIONAL PROFILE

SMP Laboratorium UM Malang

LOCATION

Malang, East Java, Indonesia

TYPE OF INSTITUTION

Private Junior High School

LESSON DETAILS

NUMBER OF LESSONS

1 lesson

DURATION

120 mins

GRADE LEVEL

Grade 8

SUBJECT/ DISCIPLINE

Physics

NO. OF STUDENTS/ PARTICIPANTS

32 (4 per group)

STUDENT READINESS

Mixed to high ability

Toll safety remains a critical concern in Indonesia, particularly in the mountainous terrain of Malang in East Java. To prevent accidents caused by brake failure, arrester beds are situated around turns to divert runaway vehicles from the main traffic and bring them to a safe and natural stop.

In this chapter, Ms Dyne introduced students to the mechanics of arrester beds through a hands-on design challenge. By designing and constructing scale models to stop a pull-back toy car, students explored the practical application of gravitational potential energy, kinetic energy, mechanical energy, and dissipation energy.

In this chapter, we learn:

- ✔ How the concepts of gravitational potential energy, kinetic energy, mechanical energy, and energy dissipation relate to braking systems, and why brake failures lead to collisions on toll roads
- ✔ The mechanism and use of arrester beds and their role in diverting and decelerating runaway vehicles to prevent collisions
- ✔ How to conduct a hands-on exercise to design, build, and test arrester beds in an uphill lane model to safely stop a pull-back toy car

In Indonesia, injuries and death rates from toll road accidents remain high. In the Malang area, toll road accidents are frequently caused by a combination of vehicle neglect, dangerous driving, and overloading. Brake failure accidents on the Pandaan-Malang route often occur because of improper gear selection while descending slopes, overuse of the brake pedal, and overheating of the brake fluid, leading to brake malfunction and loss of control.

By learning from existing incident reports and solutions, students gained knowledge on the common causes of toll road brake failures and the mechanics of arrester beds in mitigating collisions. This led to the challenge of brainstorming and designing structural and/or architectural refinements to improve the design, function, and safety of arrester beds on Indonesia's roads. This lesson applied the SOLO taxonomy to structure STEM learning outcomes and took on a qualitative approach, utilising a qualitative marking rubric to prioritise cognitive engagement and a growth mindset, respectively, rather than attaining correct answers.

Topics covered in this lesson	
Physics	Technology
Prior knowledge, covered in Grade 8 <ul style="list-style-type: none"> • Gravitational potential energy • Kinetic energy • Mechanical energy • Dissipation energy 	<ul style="list-style-type: none"> • Using AI tools such as ChatGPT and Gemini to aid understanding of technical jargon
Engineering	Mathematics
<ul style="list-style-type: none"> • Creating a new or modified uphill lane design, testing, and improving the design 	Prior knowledge, covered in Grade 7 <ul style="list-style-type: none"> • Trigonometry (calculating the slope angle and length)

Module design process

This lesson featured Physics as the lead discipline, allowing students to apply concepts of energy to derive STEM-based solutions to reduce toll road accidents caused by brake failure. It drew on students' prior knowledge from Grade 8 Physics and Grade 7 Trigonometry, which were revisited over one to two lessons to aid students in understanding how the topographical features of the Malang area such as slope steepness, length, and curvature can contribute to the likelihood of fatal accidents.

The lesson was designed to integrate the use of AI as a supportive tool to lower the barrier of entry for complex concepts and technical jargon. It was paired with instructional guidance from Ms Dyne, who monitored the information generated through conducting moderated discussions on students' understanding. This ensured that the content was accurate and aligned with curriculum requirements, such that the ideas that surfaced were relevant to the lesson. In addition, it offered an opportunity for a teachable moment, to inform students of the limitations of generative AI, giving them the opportunity to evaluate and verify the information produced. Students worked in groups to source information from either ChatGPT or Gemini (Google's AI assistant) and evaluated them against the original source articles and journals with guidance from their teacher to ensure the information was derived from credible sources and accurate.









Lesson plan

(Re)designing solutions for brake failure on toll roads

i. Desired learning outcomes and objectives

Desired learning outcomes	Rationale
 <p>1. Through watching a series of videos situated in their local context, students develop a deeper understanding of community-specific challenges, fostering empathy that can drive their motivation to problem-solve.</p>	<p>Inquiry-based learning Students navigate a complex real-world problem and engage in critical thinking to explore and investigate various design solutions, formulate evidence-based arguments, and communicate findings.</p>
 <p>2. Students create their own prototypes using provided materials or readily-available resources within the school grounds.</p>	<p>Design thinking Students undergo the iterative process of design thinking and develop their critical thinking skills, resilience, and perseverance.</p>
 <p>3. Students communicate clearly and collaborate well with their peers.</p>	<p>Collaborative learning Students practise open-mindedness, politeness, and respect as they listen to the various ideas and opinions proposed by their peers.</p>
 <p>4. Students engage in scaffolded levels of learning increasing in cognitive difficulty.</p>	<p>SOLO taxonomy Students are first introduced to the conceptual knowledge required in siloed Mathematics and Physics classes. This lesson was designed to help students draw meaningful connections between subject-specific knowledge and how they can be integrated to propose, evaluate, and refine their solutions.</p>

These learning objectives were crafted in alignment with the SOLO taxonomy:

SOLO level	Criteria description	Performance indicator
Prestructural (incomplete)	Student shows minimal understanding; responses are off-topic or irrelevant.	Ideas are disconnected or unrelated to the problem; little evidence of understanding the problem and the foundational knowledge required or developing a solution.
Unistructural (single aspect)	Student understands one relevant aspect, but lacks depth or connections.	Identifies an isolated component of the problem (e.g., only focuses on the disciplinary knowledge for technology), without exploring the broader project requirements (e.g., interdisciplinary connections).
Multistructural (independent aspects)	Several relevant aspects are understood, but not connected.	Addresses multiple components of the project (e.g., across disciplines), but components remain independent of one another.
Relational (integrated)	Makes meaningful connections between different aspects.	Integrates the content knowledge and competencies from more than one discipline into a cohesive solution with clear reasoning.
Extended Abstract (transformative)	Goes beyond the task; shows innovation, insight, or applies understanding in new ways.	Innovatively applies interdisciplinary knowledge to ideate, evaluate, and refine solutions.

Expected deliverables from the students by the end of the activities

By the end of the project, students will:

1. Present and explain the concepts underlying their design decisions, the advantages of their design, and future possibilities for further development
2. Demonstrate the effectiveness of the design of their arrester beds
3. Provide constructive feedback on the work of their peers

ii. Carrying out the lesson

The lesson comprised six stages.

Stage 1 Apperception (10 mins)

Materials required:

- Laptop (1 per class)
- Smart phone or tablet (1 per group)
- Coloured markers
- Portable white board
- STEM worksheet

Options for building materials (non-exhaustive):

- Wooden or plastic boards
- Blocks for structural support
- Protractor
- Grass and soil
- Shovel and forks

Students recapped the concepts of gravitational potential energy, kinetic energy, mechanical energy, and dissipation energy, through watching a video on roller coasters. These concepts were previously covered in Grade 8 in two lessons.



SCAN TO WATCH
Explainer video
on potential and
kinetic energy

After watching the video, students worked in pairs to share their understanding of the concepts covered. One student from the class was then randomly selected to present their understanding to the whole class, while Ms Dyne supported and corrected their response where necessary.



Students watching a video on roller coasters in class

Stage 2 Understanding the problem (20 mins)

a. Presenting the problem

Next, students were asked to read an article detailing accidents on toll roads to provide background context to the problem.



SCAN TO READ
Article elaborating
on cost of toll road
accidents



A brake-failing truck crashed near Bogor's Ciawi Toll Gate in 2025, killing eight and injuring eleven

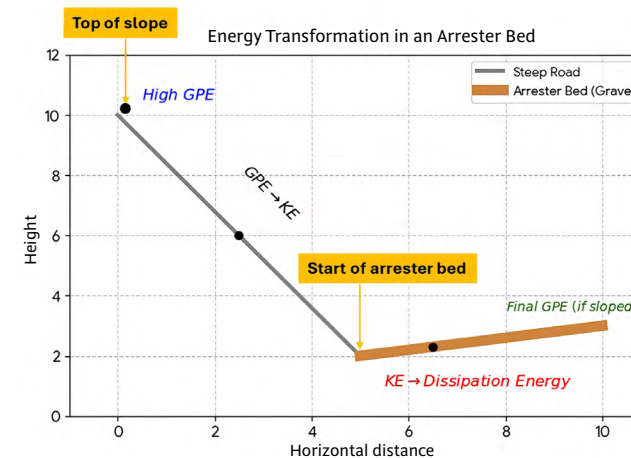
b. Understanding existing solutions

Ms Dyne then introduced students to the concept of arrester beds on toll roads. Students analysed and discussed cases of accidents on toll roads after watching another video, which detailed how arrester beds are designed to stop cars that experience brake failure on toll roads.



SCAN TO WATCH
Explainer video on the
function of arrester beds
to avoid toll road accidents

Ms Dyne brought to attention the different types of arrester bed designs shown in the video and elaborated on how they differ in architecture from those in other countries. Students were then invited to consider which design would be most effective in helping cars with brake failure decelerate, stop safely, and avoid collision. They were prompted to use their knowledge on kinetic energy, potential energy, mechanical energy, and dissipation energy to improve the design of existing arrester beds in Indonesia.



Formulas

Gravitational potential energy = GPE

$$E_p = mgh$$

m = mass (kg)

g = gravitational field strength (N/kg) (9.8N/kg)

h = height (m)

E_p = gravitational potential energy (J)

Kinetic energy = KE

$$KE = \frac{1}{2} mv^2$$

m = mass (kg)

v = velocity (m/s)

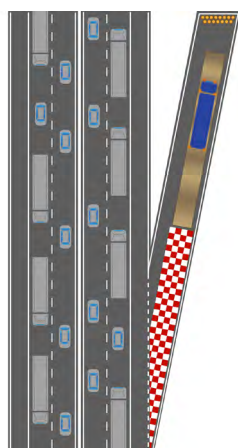
KE = Kinetic energy (J)

Mechanical energy = GPE + KE

Energy transformation in an arrester bed: Connecting concepts of gravitational potential energy, kinetic energy, mechanical energy, and dissipation energy



Truck arrester bed on highway in South Korea (top) and Germany (bottom)



$$\begin{aligned} \bar{v}_0 &= 1,6 \text{ m/s} \\ m &= 0,2 \text{ kg} \\ s &= 0,145 \text{ m} \\ \theta &= 30^\circ \end{aligned}$$

Initial energy = Kinetic energy (KE_0)

$$KE_0 = \frac{1}{2} m v^2 = \frac{1}{2} (0,2) (1,6)^2 = 0,256 \text{ Joule}$$

When brake failure occurs on a downhill slope, a vehicle's gravitational potential energy is converted to high kinetic energy. In the model simulation, the toy car possesses 0.256 Joules of kinetic energy.

Potential energy (PE_f)

$$\begin{aligned} PE_f &= mgh = mg (s \sin \theta) \\ &= (0,2) (9,8) (0,145) (0,5) \\ &= 0,142 \text{ Joule} \end{aligned}$$

Arrester beds are typically built on an incline. It stops the vehicle by gaining height and through friction. Given a 30-degree incline as shown in the diagram above, a car moving up the slope converts the kinetic energy to potential energy (0.142 Joules).

Dissipation energy (DE)

$$\begin{aligned} E_0 &= E_f \\ KE_0 + PE_0 &= KE_f + PE_f + DE \\ KE_0 &= PE_f + DE \\ DE &= KE_0 - PE_f \\ &= 0,256 - 0,142 = 0,114 \text{ Joule} \end{aligned}$$

Contact with the gravelled surface results in resistance and friction. Kinetic energy is rapidly converted into dissipation energy (0.114 Joules), slowing the car to a stop.

c. Solution ideation

Ms Dyne then assigned students into groups of four and instructed them to ideate and discuss solutions to modify the design of the existing arrester beds.

Students were briefed on the materials available and informed of the requirement that their model must ensure that cars would stop safely in the absence of collision. Students were given the freedom to design their own arrester beds based on what they considered to be the most effective solution. They were reminded to consider how the angle of inclination affects gravitational force acting on the car. As such, emphasis was placed on precise measurement to optimise safety and mitigate collision risks.

A worksheet was provided to guide students to use more than two disciplinary concepts (Science, Technology, Engineering, and Mathematics) in their solution design.

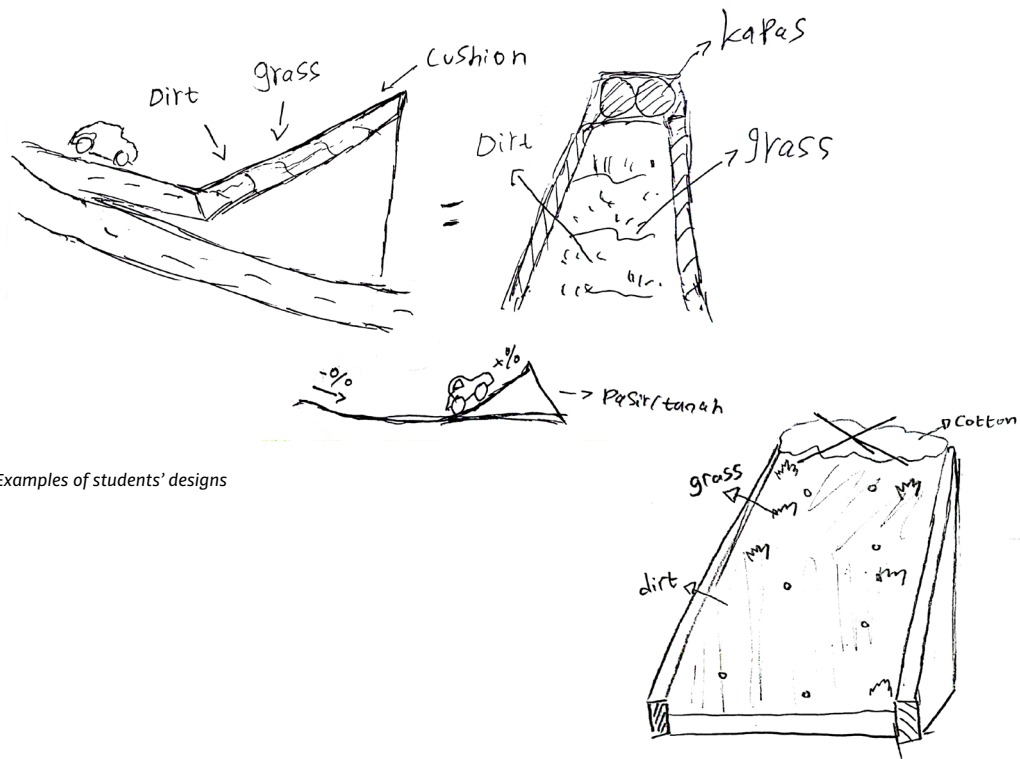
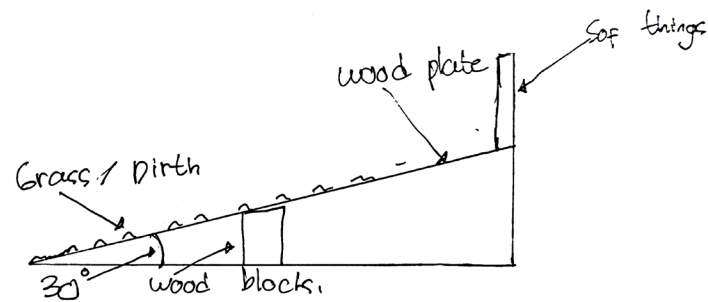
Component	Target disciplinary outcomes	I used the concept of (sample student responses)
Science	Integrates or connects scientific principles to explain a real-world phenomenon in the project	To predict if a collision will occur when a car of a given mass is subjected to a simulated brake line failure
Technology	Designs a functioning prototype or model with purposeful integration of two or more technological concepts/ideas	To look for design examples to create my model based on logical and scientific justification
Engineering	Engages in the iterative engineering design thinking cycle to test and improve the solution	To see if the design and construction of the arrester bed can adequately stop the momentum of a car given its mass
Mathematics	Support design decisions with data-informed analysis, modelling, or calculations	Calculate the optimal angle of elevation for the arrester bed to stop a car of a given mass

STEM concept table featured in the worksheet



Students brainstorming and designing the solution

Students were also tasked to draw a diagram of their arrester bed in their worksheet and detail how they would simulate the testing and refinement process.



Examples of students' designs

Stage 3
Experimentation
(30 mins)



a. Constructing a model of their solution

Guided by group-specific design parameters, students autonomously selected and used tools and materials sourced from their teacher and/or the school grounds to construct a model of their arrester beds. This involved identifying material analogues that simulate real-life functionalities such as high-resistance surfaces and shock absorbance. Students did not focus on modelling their designs to scale, but explored relevant dampening mechanisms to make their design as effective as possible using the pull-back toy cars provided to simulate brake line failure.

In addition, to reinforce the iterative nature of design thinking and promote a culture of continuous improvement, Ms Dyne offered additional lab time, enabling students to optimise their designs beyond class hours.



Students gathering soil on school grounds for their set-up

Basic materials provided

- Wooden planks or plastic boards
- Blocks for structural support
- Protractor
- Shovel and forks
- Bucket
- Mechanical pull-back toy cars or trucks

Student-sourced materials

- Soil
- Grass
- Plastic bottle
- Fabric
- Used tires



Students constructing their models and measuring for angle accuracy



b. Testing and review

Following model construction, students tested the effectiveness of their arrester beds using a toy pull-back car. If the car could stop completely without falling off the slope or crashing into an obstacle, the model and design were deemed to be effective. During this phase, students were also guided to reflect on the outcome and effectiveness of their solution. This was an important step in informing subsequent iterations, where students strategically modified the design of their solution and the materials used to optimise passenger and vehicle safety.



Students testing the effectiveness of their arrester beds

Stage 4
Presentation and trials
(30 mins)

Lastly, students presented their models to the class with a demonstration on how it works. Each group shared their thought process behind the design, referencing their worksheet and illustrations to justify their design choices. The presentation time was limited to 5 minutes per group, which included a question-and-answer section and receiving feedback from their peers. The peer-review phase encouraged transparent idea sharing. For example, student critique helped surfaced critical design trade-offs, such as the impact of having a solution with multiple speed bumps on passenger comfort and safety.

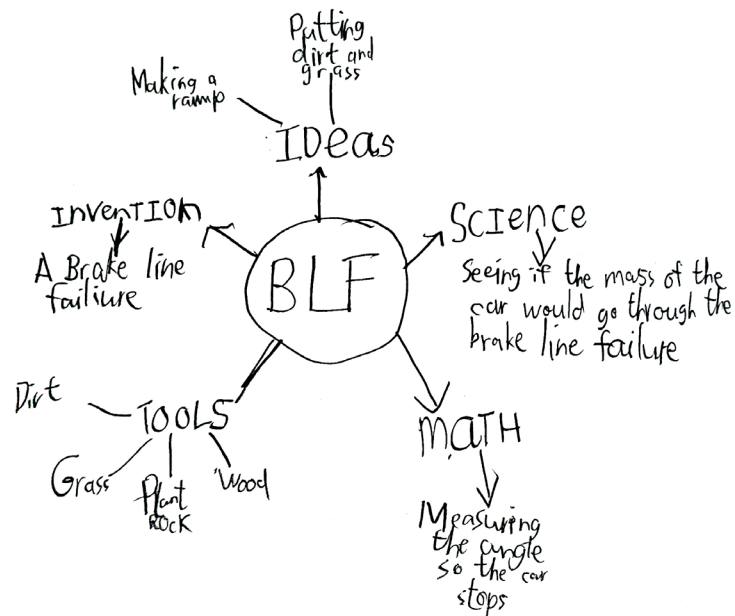
Ms Dyne then followed up with consolidated feedback to highlight the strengths and opportunities for improvement at the end of the presentations.

a. Individual reflection using mind maps

Students reflected on the activity individually, using mind maps as a reflection tool.

b. Group reflection in “circle time”

Students gathered for “circle time” to discuss their experience moving through the lesson. They shared their personal moments of success and learning during the activity, analysed their unsuccessful attempts, and listened to feedback to better understand how they could improve their group’s design.



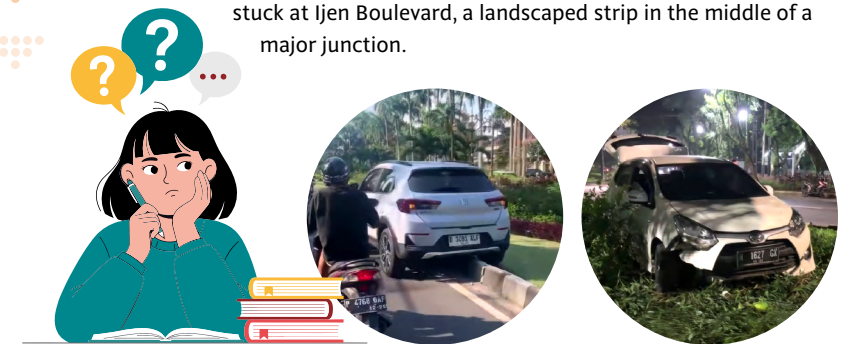
Examples of student reflection

Stage 5
Conclusion and evaluation
(20 mins)

Stage 6
Extension task
(5 mins)

To enhance students’ level of cognitive engagement, the curriculum integrates extension tasks, which involve applied challenges that require the transfer of theoretical knowledge to other real-world phenomena or challenges. This pedagogical approach helps the teacher to gauge students’ ability to apply the concepts learnt accurately.

For this lesson the extension task involved presenting students with a real-world problem in Malang city, where cars frequently get stuck at Ijen Boulevard, a landscaped strip in the middle of a major junction.



Students were asked why they thought this happened, and initially hypothesised that it was due to driver inattention or excessively high driving speed. Ms Dyne then gave students time to examine whether there were any construction flaws in the boulevard’s design, given its position in the middle of a junction.

Ms Dyne then posed the task:

“How can we solve the frequent problem of cars getting stuck in the median strip of Ijen Boulevard, in Malang city? What ideas can you propose to solve this? Use the Physics concepts you have learned (i.e., gravitational potential energy, kinetic energy, mechanical energy, and dissipation energy) to support your ideas.”

Through this activity, students were tasked to analyse the problem more comprehensively, considering not only human behaviour but also structural design flaws to design a solution to prevent similar incidents from happening.

This task was assigned as group work to be completed at home, to be submitted and discussed in the next lesson.



Tips

1. Students may experience difficulties in identifying and articulating the STEM concepts used in their solution design. For example, clarification on the correct application of trigonometry and how it applies to their models may be required. You may wish to provide a list of the relevant topics they have learnt and sentence starters to guide them as they fill out the table in their worksheet.
2. Students may require permission when sourcing and using additional materials from the school grounds. You may wish to establish a procedure for students to procure the materials required.

iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
Students have weak mathematical understanding on angles and basic trigonometry, which affects their ability to design and analyse the breakline system.	Revisit relevant mathematical concepts at the beginning of a lesson to gauge students' understanding. You may wish to engage students in various modalities of learning, such as through visual aids, hands-on activities with real-life examples (e.g., measuring angle of a slide at a school playground), and self-paced videos. This can help students grasp the concepts and its application more comprehensively.
Limited availability of tools and materials restricts the optimisation of students' models.	Encourage students to use alternative materials and to consider analogous modelling. This fosters resourcefulness and promotes creative problem-solving while meeting the learning outcomes.

Challenge	Possible solution
Some students are more interested in constructing the model rather than understanding the related scientific and mathematical concepts.	Targeted questioning as students build their models can encourage technical discourse as students explain the scientific principles and rationale behind their design.
Time constraint due to two-hour single-session implementation limits the opportunity for students to engage in the full iterative cycle of the design thinking process.	Provide a structured workflow with clear instructions. Introduce essential concepts before the STEM lesson or assign preparatory tasks to ensure students are ready for the STEM activity.
Teachers may face difficulties facilitating STEM learning in a single two-hour session as the time required for multidisciplinary instruction and effective integration across disciplines may require a longer duration.	Strengthen students' foundational knowledge before STEM lesson implementation. You may wish to prepare guiding questions or scaffolding tools to support interdisciplinary facilitation.



Author's reflections

Science learning is indeed not merely about focusing on students' mastery of concepts. Rather, I believe that Science can be used for much more, including developing one's thinking skills, ability to persevere and collaborate, and foster a growth mindset. In this digital era, we consistently strive to teach students about technology, and to use technology to cultivate informed digital learning experiences. Amidst this, we endeavour to engage students in projects or challenges that have a more tangible impact on the surrounding environment, such that their learning outcomes can add value to their community, making learning more meaningful. For example, our school can partner with a community-based organisation to propose ideas for improving the quality of life of their region sustainably.

Ms Dyne Rizki Puspitasari

The Seed Hands Project: Saving Biodiversity One Seed at a Time

Ms Kim Minju



INSTITUTIONAL PROFILE

**Daegu Foreign
Language High School**

LOCATION

South Korea

TYPE OF INSTITUTION

Public high school

LESSON DETAILS

NUMBER OF LESSONS

8 lessons

DURATION

50 mins/ lesson

GRADE LEVEL

Grades 10 & 11

SUBJECT/ DISCIPLINE

Integrated Science, Life Science

NO. OF STUDENTS/ PARTICIPANTS

185

STUDENT READINESS

Mixed to high ability

In an age of climate crises, seed biodiversity is increasingly threatened. Conservation is one way scientists ensure plant biodiversity is maintained. The Baekdudaegan Seed Vault in South Korea is one of two seed vaults in the world, with the mission to preserve the seeds of wild plants. In this chapter, Ms Minju walks us through a unique STEM module that incorporates biodiversity, climate change, seed conservation, and the use of visual communication to promote the preservation of wild seeds in their community.

In this chapter, we learn:

- ✓ How to integrate STEAM-based learning to address the complex issues of biodiversity loss and conservation
- ✓ How to identify, analyse, and map relationships between key stakeholders in biodiversity loss and conservation
- ✓ To compare differences in national and global conservation strategies
- ✓ To apply future forecasting tools to predict the impact of climate change on biodiversity in the future
- ✓ The scientific procedures to collect, select, dry, and conserve seeds



Across the globe, climate change, habitat loss, and industrial agriculture have accelerated biodiversity decline. According to UN reports, 75% of cultivated plant seed varieties have been lost over the past century, threatening environmental diversity, food security, and the survival of future generations.

The Seed Hands Project is a STEAM-based educational initiative grounded in **UN Sustainable Development Goal 13: Climate Action** and **Goal 15: Life on Land**. Students learned about the biological principles of seeds and genetic diversity (Science); employed design systems for seed preservation (Technology and Engineering) and community sharing; created accessible and persuasive outreach materials (Arts); and developed the operational framework and numerical model for a “Seed Savings” proposal (Mathematics).

The Seed Hands Project aligns with the Daegu Foreign Language High School’s common curriculum for the 10th grade Integrated Science and 11th grade Life Science courses. In particular, this project was designed to integrate with the “Biodiversity and Conservation” unit of the 10th grade Integrated Science course. Led by Science teachers, the project enabled students to explore the scientific aspects of biodiversity conservation while also examining its social and ethical dimensions. The lessons were conducted over eight sessions during regular science class time and include both classroom-based inquiry activities and field-based conservation activities.

Topics covered in this lesson	
Science	Technology
<ul style="list-style-type: none"> • Seed vault preservation: Technology and operations in advanced seed preservation facilities • Biodiversity: Importance and connection to climate change • Seed conservation: Scientific procedures for seed collection, selection, drying, labelling, recording, and deposition in a seed vault 	<ul style="list-style-type: none"> • Digital and information literacy: Using search techniques and tools to collect and evaluate scientific information and data • Digital design and communication: Using Canva, Google Slides, and other software to share, discuss, visualise ideas, and create promotional material • Maker technology: Application of Computer-Aided Design (CAD) and laser cutters to create plant name tags
Engineering	Mathematics
<ul style="list-style-type: none"> • The engineering design thinking process: From problem definition to idea concretisation, development of the “Seed Savings” proposal, and feedback-based iterative design • Systems thinking and structuring: Identifying the components and relationships of complex problems through stakeholder mapping 	<ul style="list-style-type: none"> • Data interpretation: Interpreting data such as climate change graphs, Shared Socioeconomic Pathway (SSP) scenario graphs and statistics • Prediction modelling: Analysing the ripple effects of dynamic changes and developing potential scenarios using tools such as the Futures Wheel

A lesson in preserving biodiversity

The project began with a study of Korea’s biodiversity conservation status, enabling students to understand both the necessity of seed preservation and the importance of international cooperation. Students then carried out a seed saving activity using plants cultivated within the school grounds. After harvesting, drying, sorting, and packaging the seeds to ensure long-term viability, the final seed samples were officially deposited in the **Baekdudaegan Global Seed Vault (BGSV)** — one of two seed vaults in the world.

This allowed students to contribute directly to the national and international network of biodiversity conservation. To raise public awareness, students designed a “Seed Savings” proposal and produced a leaflet and presentation introducing the seed banking process and its significance. Through these experiences, students developed scientific knowledge, creative expression, and a strong sense of global citizenship.



(top) Researchers at the BGSV conducting research

(right) The BGSV in South Korea is one of the two seed vaults in the world



SCAN TO READ
More about the
Baekdudaegan
Global Seed Vault



The **Baekdudaegan Global Seed Vault** in South Korea currently hosts the seeds of more than 6,000 wild plant species across the world. The first established Svalbard Global Seed Vault located in Norway primarily stores seeds of crops, while the BGSV stores seeds of wild plants.

The main aim of the BGSV is to preserve global wild plant diversity and ecosystem health in the face of major disasters such as climate change, environmental pollution, and natural disasters.

After learning about the purpose of seed vaults and the importance of seed conservation, students engaged in **practical problem-solving** by exploring various plant species within their school, collecting seeds, and depositing them into a seed vault. They also underwent **creative problem-solving** by designing a “Seed Savings” proposal and produced outreach materials to promote the value of seed conservation. Through these activities, students developed scientific knowledge, collaborative skills, and a sense of responsibility as agents of change for sustainable development.

Guiding questions for designing an integrated STEM project-based learning term on sustainable development

1 Context and problem definition

- What is the context of your community/classroom?
- What is the problem you are trying to tackle — what is your primary focus (e.g., teaching a subject-specific concept or skill, or addressing a larger community or global issue)?

2 Understanding the context

- How will you introduce the urgency of biodiversity conservation and connect it to students’ lived experiences?
- What global and national data or case studies will you use to contextualise the Seed Hands Project for your students?



3 Lesson design

- How will you integrate Shared Socioeconomic Pathways (SSP) Future Scenario Analysis into your lesson so that students can make evidence-based predictions?
- What scaffolding will you provide for STEM content and skills (e.g., seed biology, storage engineering, trend line analysis) before project work begins?
- How will you ensure students consider both local and global perspectives when designing their “Seed Savings” proposal?

4 Lesson implementation

- How will you structure team roles to ensure balanced participation during seed saving, proposal design, and outreach?
- What strategies will you use to build student empathy for biodiversity conservation and the seed vault’s mission?

5 Evaluation and extension

- How will you facilitate meaningful peer and cross-class feedback on both the scientific and communicative aspects of student work?





Module plan

The 8-Week Seed Hands Project

i. Desired learning outcomes and objectives



Knowledge and understanding

- Students explain the impact of climate change on ecosystems and biodiversity, using scientific cases and international agreements to support their explanations.
- Students recognise the scientific and social significance of seed vaults in responding to climate change and conserving biodiversity.



Process skills

- Students use scientific methods to explore various plant species within the school. They collect and analyse data to understand their ecological characteristics, and harvest and prepare the seeds.
- Students develop problem-solving and teamwork abilities by collaboratively planning an outreach “Seed Savings” proposal.



Values and attitudes

- Students develop a strong sense of responsibility toward environmental issues, with deep empathy for the need to address climate change and conserve biodiversity.
- Students recognise the importance of personal and societal actions for sustainable development and cultivate a proactive attitude for solving such problems.

ii. Carrying out the module



The module spanned eight lessons, each anchored by a key inquiry question.



Tips for designing and conducting the multi-disciplinary module

1. **Context setting:** Begin with compelling global and local data on biodiversity loss, including visual examples (graphs, satellite images, case studies). This helps students see the urgency of the problem.
2. **SSP scenario guidance:** Teach trend line analysis and graph interpretation prior to the module to equip students with the skills to work confidently with shared socioeconomic pathways (SSP) data for future prediction exercises.
3. **Empathy building:** Use stories, videos, or interviews with conservation experts to help students empathise and connect with the seed vault’s mission.
4. **Technical skill scaffolding:** Provide workshops on seed drying, moisture measurement, packaging procedures, and basic engineering design principles before the seed processing phase.
5. **Global perspective in design:** During the “Seed Savings” planning phase, connect students’ learning to global crop diversity issues, in addition to local needs.
6. **Collaboration infrastructure:** Assign clear team roles (data analyst, biologist, engineer, communicator, designer) to ensure balanced participation
7. **Feedback culture:** Prepare students to give constructive peer feedback by providing a rubric or checklist; include both teacher and cross-class review sessions.



For more details on this module, refer to Ms Minju’s briefing slides.



SCAN TO ACCESS
The full slide deck and student worksheets

Lesson 1
What will our future look like?

Key inquiry question:

WHAT WILL OUR ENVIRONMENT LOOK LIKE IN A CLIMATE-ALTERED FUTURE?

Materials used:

- Ageing filter (application for visualising future self as an older adult)
- Shared socioeconomic pathways (SSP) climate scenario graphs (data visualisations of SSP)
- Summaries of SSP scenarios (simplified text-based descriptions)
- Curated multimedia materials:
 - Videos (on sustainability challenges and biodiversity)
 - Articles (on UN Sustainable Development Goals)
 - Related global issue cards

a. Introduce the concept of life expectancy

Students were invited to imagine their future selves by using an ageing filter application to help them personally engage with and reflect on how the climate crisis and ecological shifts may affect their lives in the future.

b. Analysis of shared socioeconomic pathways

Students then analysed shared socioeconomic pathways climate scenario graphs, to grasp the projected transformations that await future societies. They interpreted summaries of the SSP scenarios to deepen their understanding of the consequences associated with different global responses to climate change.

Ms Minju prompted students to inquire: *Where are we now, and what kind of future can we choose to have?*

This encouraged students to respond by using evidence from the data presented in the SSPs. Students were guided to conduct simple calculations using Microsoft Excel to predict future scenarios to support their answer.

SSPs are scenario frameworks from the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report, which combine socioeconomic pathways with future greenhouse gas emission level predictions.

SCAN TO READ
SSPs explained

SCAN TO READ
A summary of the assessment report



Deforestation is among the main causes of biodiversity loss

Lesson 1.
Taking the First Step Toward the Future:
Identifying Sustainability Challenges

Climate Change Scenario

Create trendline: What will the future be like for our region (Daegu)?

1. Provide some data on the average temperature increase in Daegu over the past 50 years
2. Use Excel to create a scatter plot graph
3. Create the optimal trend line and equation
 - Use Excel functions to add the optimal trend line
 - Display the trend equation and coefficient of determination (R²) on the graph.
 - Compare which function fits best and understand the meaning of mathematical modeling.
4. Predict future temperatures 50 years from now and imagine scenarios.

Students were presented with SSPs and guiding questions on how to use the data provided to predict future scenarios

c. Exploring future issues: UN Sustainable Development Goal connections (SDG 2: Hunger, SDG 10: Inequality, & SDG 15: Life on land)

Through a rapid review of curated videos and articles, students examined real-world examples of sustainability challenges, in particular those related to biodiversity. They explored the complexity and urgency of these future issues. During this time, students evaluated the reliability of information sources, compared materials from diverse perspectives, and interpreted visual information.

Lesson 1.
Taking the First Step Toward the Future:
Identifying Sustainability Challenges

Exploring Future Issues

- Look at examples of sustainability issues related to biodiversity using videos, news articles, and cards.
- Choose the issue you think is most urgent and write down why.
- Define the issue and write down why it must be resolved.

Examples of resources and instructional prompts for students to reflect upon

Pedagogical considerations

- Begin the lesson with life expectancy statements and the ageing filter application.
- Foster collaborative critical thinking and information integration by combining individual research with group comparative analysis and discussion.
- Support student agency and help them become active problem-posers rather than passive receivers of information, by encouraging student-driven selection of issues and the formulation of their own inquiry questions.

Lesson 2 Multiple perspectives, one world — Stakeholder mapping and biodiversity

Key inquiry question:

WHY DO PEOPLE VIEW BIODIVERSITY LOSS DIFFERENTLY AND HOW ARE THEIR INTERESTS CONNECTED TO THIS ISSUE?

Materials used:

- Data or background materials on various stakeholders (individuals, organisations, industries, communities, nations)
- Search tools
- Shared worksheets for stakeholder mapping and key stakeholder analysis

First, Ms Minju posed the guiding question: *Are the issues from our previous lesson shared concerns for everyone?* This prompted students to reflect and recognise how such problems are embedded within complex social structures, such that differing positions and interests can come into conflict.

This led to the introduction of the concept of **stakeholders** and set the stage for this lesson on exploring diverse perspectives within a given issue.

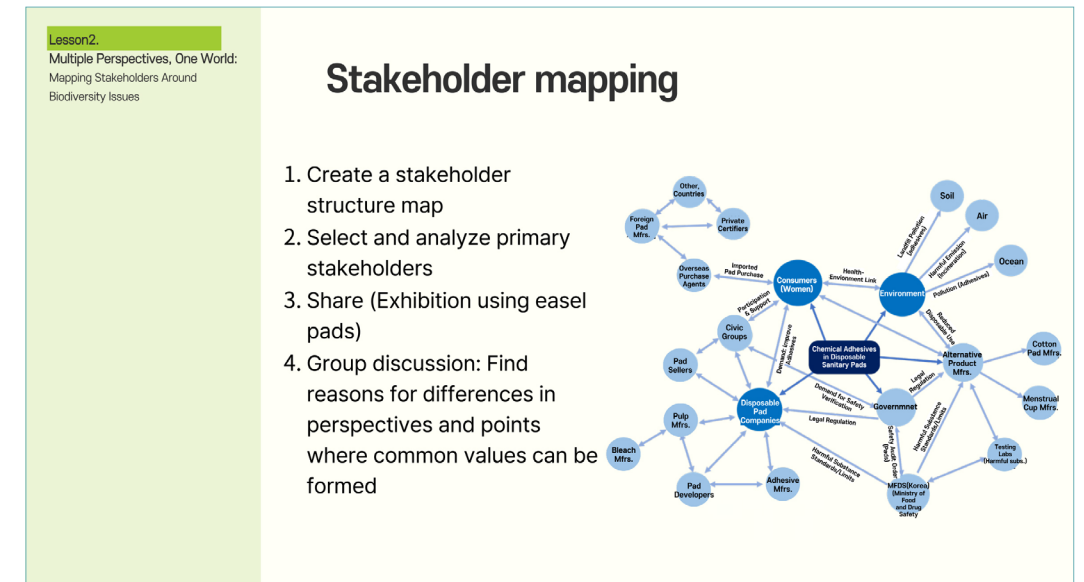


Stakeholders finding collaboration despite conflicts and overlapping interests

a. Mapping the stakeholder landscape

Students were briefed on the criteria for becoming a primary or secondary stakeholder, as well as the criteria for the exclusion of stakeholders. They then identified a range of stakeholders related to a chosen issue (e.g., biodiversity loss), including individuals, organisations, industries, communities, and nations.

They created a stakeholder network map that visually represented the relationships among the stakeholders — highlighting the degree of influence, proximity of relationships, and the direction of interests — rather than simply listing them.



Stakeholder map: Instructions and example

b. Identifying and analysing key stakeholders

Students either worked individually or in groups to select three key stakeholders and provide a summary of each stakeholder's perspective on the issue and the reasons behind it. They analysed potential areas of conflict and areas of overlapping interests to assess the possibility of collaboration among the chosen stakeholders.

Pedagogical considerations

- Promote awareness of diverse perspectives and the complexity of social systems by helping students concretise abstract ideas through visual schematisation, (e.g., stakeholder mapping using visual templates and instructional aids).
- Deepen interaction-driven thinking through a student-led discussion cycled around sharing drafts of their work, receiving and providing peer feedback, and reframing their drafts based on the responses.
- Use digital sharing platforms like Padlet to present group ideas.

Lesson 3

Beyond borders — Comparing national strategies and understanding global cooperation

Key inquiry question:

HOW DO NATIONAL BIODIVERSITY AND CLIMATE STRATEGIES DIFFER ACROSS COUNTRIES, AND WHY IS GLOBAL COOPERATION ESSENTIAL DESPITE THESE DIFFERENCES?

Materials used:

- Country-specific primary sources: government reports, official websites, policy documents, articles from credible news outlets
- Visual presentation tools (e.g., slide presentation software)

Students were first provided with examples that demonstrate how the issues explored in the previous lesson are addressed differently between countries. Ms Minju highlighted how response strategies vary depending on social, cultural, and economic contexts. This led into the third lesson where students examined and contrasted national policies on biodiversity and climate change.



Global leaders convene at the 2022 UN Biodiversity Conference (COP15)

a. Researching national policies (individual activity)

Students were guided to select a country of interest and conduct research on the country's policies on biodiversity and climate change, using primary sources such as government reports, official websites, and policy documents.

They were required to go beyond surface-level summaries to analyse the selected policy on a national level — examining how social, cultural, and economic factors shape the country's approach to biodiversity and climate challenges. Students had the opportunity to review and reconstruct information from primary sources such as government/agency websites, news materials, and policy reports, as they gained experience in interpreting and comparing these complex texts.

This process reinforced the importance of understanding that the policies were not just generic or universal in nature, but rather situated within the realities of the nation's own environment and culture.

b. Group policy presentation and collaborative discussion

Ms Minju then grouped students such that each member represented a different country. Students were required to present their research to their group members in the form of a slide deck sharing the key policy features, priorities, and challenges specific to their nation.

Through discussion, students identified commonalities and differences among national approaches and collaboratively derived insights into the conditions and challenges for meaningful global cooperation.

Tip

Encourage each member to compare and analyse the data and policies within the broader socio-cultural and economic contexts of the other countries. This helps students understand how values, resources, and governance structures shape different approaches to the same global issue.

Lesson 3:
Beyond Borders:
Comparing National Strategies and
Understanding Global Cooperation

Research & Discussion: National Climate Change & Biodiversity Efforts

Assignment Guide

Research your assigned country's efforts and create a 3-5 page PPT presentation to share with your group.

<Research Focus>

- Relevant climate change agreements/conventions.
- Current status of climate change mitigation/adaptation efforts.
- Current status of biodiversity conservation efforts.

<Requirements>

- PPT Page 1: Include PPT Title, Country Name, Student ID, Name, Table of Contents.
- Sources: Must include at least one source from the assigned country (as perspectives can differ). Cite all sources properly.
- Last Page: Propose one relevant discussion topic for the next session.

Discussion Guide (Process: Opening - Rebuttal - Closing)

1. Appoint a note-taker for the group.
2. Select a discussion topic related to climate change where national interests or positions might differ. (Can use proposed topics or choose a new one).
3. Ensure every group member participates at least once during the discussion.
4. Reach a group conclusion on the topic.

Assignment instructions for lesson 3

To facilitate smooth transition to the next lesson, students were prompted to consider the collaborative aspect of problem-solving by asking: *Who do we need to work with to address this issue — not just scientists, but also policymakers, citizens, international organisations, and other collaborators?*

This question encouraged students to think beyond the disciplinary boundaries of Science and recognise the need for intersectoral and global cooperation.

Pedagogical considerations

To help students appreciate the specificity of the policies and strategies implemented to meet country-specific challenges and understand how a one-size-fits-all approach cannot be applied, have students reflect on their insights gained from the research process and group discussion. Encourage them to articulate how their understanding of biodiversity and climate strategies evolved through the cross-national comparison.

Lesson 4
Seed conservation
pioneers

Key inquiry question:

WHY DID SOME RISK THEIR LIVES TO PROTECT THE SEEDS, AND WHAT DOES THAT MEAN FOR OUR GENERATION TODAY?

Materials used:

- Video materials on the work of two key historical figures in seed preservation (e.g., Nikolai Vavilov, Ikjeom Mun)
- Character cards of the two historical figures in seed preservation
- Video resources on the background and role of the Baekdudaegan Global Seed Vault
- Discussion prompts and summary activity sheets for small-group work

In this lesson, students learned about Nikolai Vavilov and Ikjeom Mun (two historical individuals who had risked their lives during times of crisis to ensure seed preservation and dissemination), the Baekdudaegan Global Seed Vault, and contemporary efforts to preserve global biodiversity.

a. Researching historical figures

Students investigated acts of seed preservation carried out by Nikolai Vavilov and Ikjeom Mun, using teacher-prepared video materials and character cards.



They were asked to reflect on the following prompts:

- Why did they choose to save seeds under life-threatening circumstances?
- What do their choices reveal about the value of biodiversity and the role of seeds in human survival?
- How are their decisions still relevant to the challenges we face today?

Through this reflection, students came to recognise that biodiversity was not simply about conservation, but also about sustaining ecosystems and ensuring the future of human life.

b. Understanding the Seed Vault

Students learned about the history and role of the Seed Vault, a global seed preservation institution located in the **Baekdudaegan National Arboretum**, through teacher-selected video resources. They were also introduced to the ethical, ecological, and social values associated with seed preservation today.

c. Connecting back to the Seed Hands Project (SDG 13: Climate action & SDG 15: Life on land)

Students considered past seed conservation cases alongside the contemporary role of the Seed Vault. They related these examples back to the objectives of the ongoing Seed Hands Project, and addressed the question “*Why must we preserve seeds now?*” through small-group discussions and summary activities.

Tips

- Emphasise scientific connections throughout the lesson to provide equal focus on disciplinary connections and socio-economic implications.
- Guide students to make clear connections between the historical examples and current examples and practices of seed preservation and conservation.



Lesson 5
Future forecasting

Key inquiry question:

WHAT MIGHT THE FUTURE LOOK LIKE IF WE PROTECT — OR FAIL TO PROTECT — BIODIVERSITY TODAY?

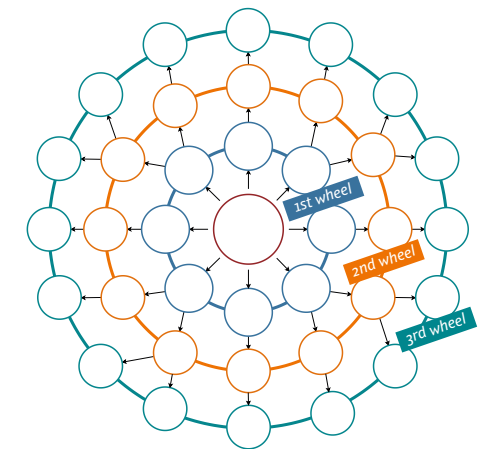
Materials used:

- Futures Wheel and Futures Cone templates
- Scenario writing worksheets, including prompts for developing characters, environmental setting, events, and types of change
- This lesson references source material on the Futures Wheel and Futures Cone from the book *함께 해보는 과학기술 쟁점해결과 실천 ENACT 프로젝트*. 박영 (Solving Science and Technology Issues Together: The ENACT Project), a story by Lee et al. (2022)¹

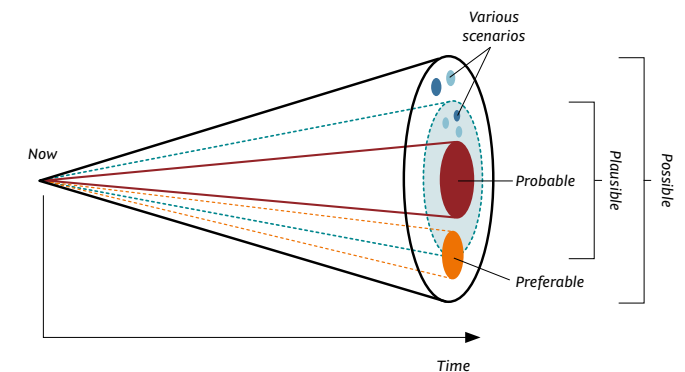
The students were prompted to recall past examples of seed conservation from the previous lesson with a guiding question: *What will happen in the future if we do not protect seeds now?*

The guiding question encouraged students to shift their thinking toward future-oriented perspectives, linking the historical cases with the current crisis and the need for forward thinking.

Ms Minju then introduced two forecasting tools, the **Futures Wheel** and **Futures Cone** and explained the purpose and structure of the day’s activity.



Futures Wheel



Futures Cone

1. Lee, H., Hwang, Y., Ko, Y., Choi, Y., Ok, S., Nam, C., Sim, S., & Kim, G. (2022). *함께 해보는 과학기술 쟁점해결과 실천 ENACT 프로젝트* [Solving Science and Technology Issues Together: The ENACT Project]. Park Young Story.

a. Creating a Futures Wheel


Students worked in groups to use the Futures Wheel to map out the ripple effects of a specific issue. They were guided to brainstorm and select issues specific to SDG 13 and 15, in line with the context of the module. The issues chosen varied by group, and students took charge of defining their topics of interest. By identifying the **primary, secondary, and tertiary impacts**, and plotting them using the Futures Wheel, they were able to visualise the interconnected consequences that could arise.

Lesson 5.
Envisioning the Future:
Forecasting with Futures Wheels and
Futures Cones

How to create a Future's Wheel

Let's use the Futures Wheel to write down the ripple effects (impacts) that may arise in the future due to issues.

- Write down the social ripple effects that may occur in the second stage as a result of the ripple effects in the first stage and create the second stage. Then, expand to the third and fourth stages of ripple effects.
- Consider the first-order social ripple effects that could arise from the issue in question across various fields, and list them around the central issue to complete the first wheel. Think about the areas most directly affected by science and technology-related issues.
- Create a second wheel. Then expand to third and fourth-order ripple effects.
- After expanding the wheels as much as possible, add arrows to indicate causal or correlational relationships between social ripple effects if they interact with each other.



How to create a Futures Wheel

b. Creating a Futures Cone

Based on the ideas derived from the Futures Wheel, students created a Futures Cone to visualise the range of possible changes over time. This process helped them construct their understanding on how today's decisions can lead to diverse future outcomes, reinforcing the significance of proactive choice-making and action in protecting biodiversity.



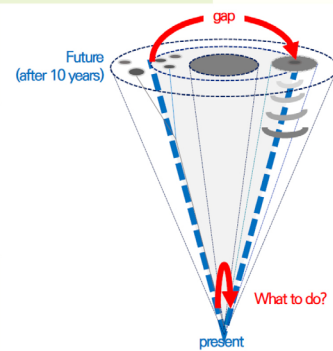
South Korean youth driving climate action through legal and social change

Lesson 5.
Envisioning the Future:
Forecasting with Futures Wheels and
Futures Cones

How to create a Future's Cone

Our goal is not to make accurate predictions, but to consider a variety of plausible future societies.
Not a future filled with fantasy and imagination!
We need future predictions based on evidence!

- Visualization of futures by group (draw using at least three colors): possible: black, probable: blue, desirable: red
- Comparison of current gaps and future gaps
- When is the best time to make changes?



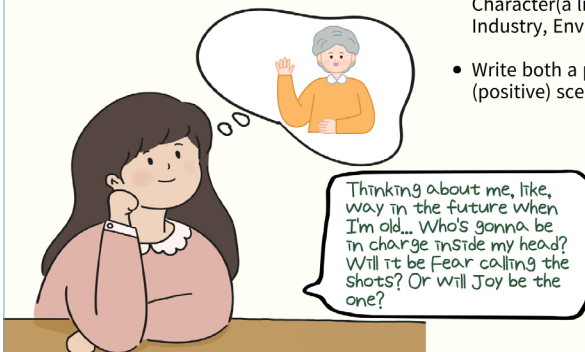
How to create a Futures Cone


Lesson 5.
Envisioning the Future:
Forecasting with Futures Wheels and
Futures Cones

Writing Future Scenarios


Let's imagine a concrete and realistic future based on what we have seen using future prediction tools.

- Include the following elements in each scenario: Main Character (a living organism), Ecosystem, Time period/Setting, Industry, Environmental conditions.
- Write both a pessimistic (negative) scenario and an optimistic (positive) scenario. (around 500 Korean characters.)





Think like anxiety



Think like joy

How to apply the futures prediction tools to generate future scenarios

Pedagogical considerations

- Students should review sufficient examples to clearly understand the structure and use of the Futures Wheel and Futures Cone.
- Guided facilitation during the scenario writing process can ensure that students' scenarios avoid becoming emotionally charged or overly extreme and remain thoughtful and grounded, with future predictions based on scientific reasoning.

Lesson 6
Telling the story of life
— Plant investigation

Key inquiry question:

WHAT MEANING DOES MY ASSIGNED PLANT HOLD FOR ME, MY COMMUNITY, AND THE ECOSYSTEM — AND WHY IS IT WORTH PROTECTING?

Materials used:

- Campus plant map
- Observation worksheet
- Digital device (to conduct internet search and collect information on their plant)
- Biological reference materials
- Computer aided design (CAD) software & laser cutter
- Design planning sheet

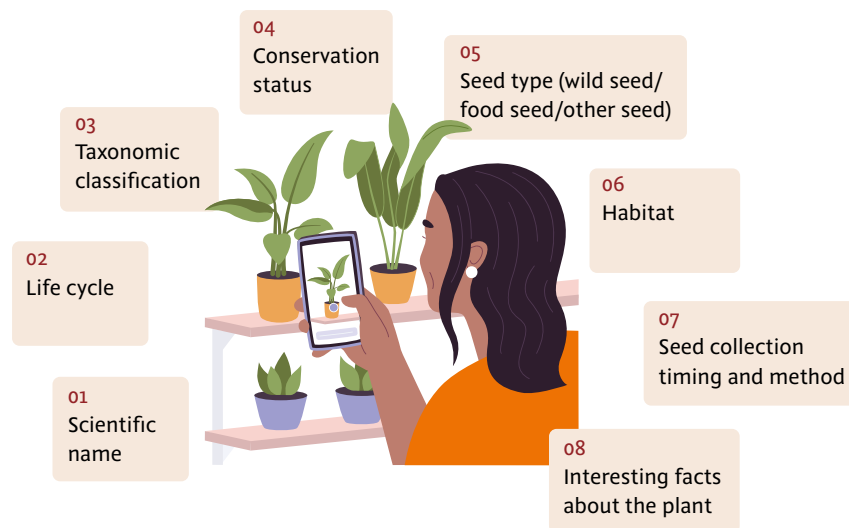
Through individual investigation, students were encouraged to develop their personal stories and reflections on their seed conservation experience. A report was written based on their investigations and research. The investigation process is detailed below.

a. Plant identification

The school grounds were divided into specific zones with a zone assigned to each student group.

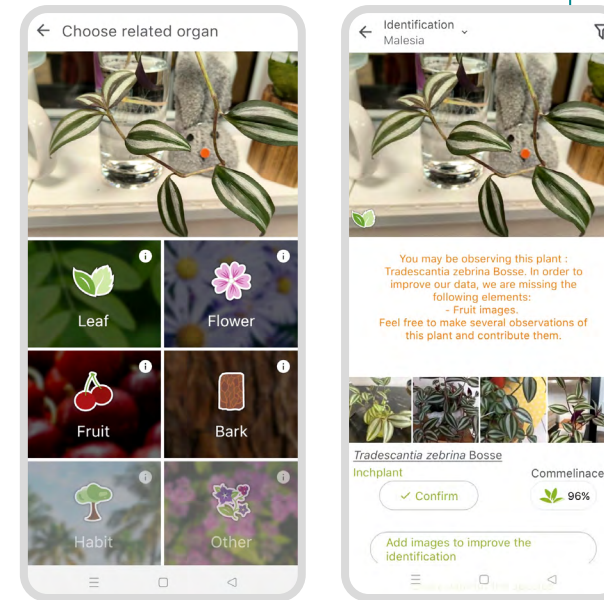
Using species identification software *Moyamo* and *Daum*, students identified and selected a plant species of their choice from the plants growing within their assigned zone.

Students researched their assigned plant by exploring the plant's ecological role, its relationship with humans, and its historical or cultural significance. Research content includes the plant's:



Tips

- Check the distribution and accessibility of plants on campus before assigning them to students, to ensure that each student can reliably observe and care for their assigned plant.
- Educate students to recognise their research subjects, not simply as study objects but as living beings that require protection.
- Ensure that the necessary tools, materials, and sufficient time are secured in advance for the name tag design and production process.
- Provide guidance to verify the reliability of biological information, including how to assess sources and cross-check facts during research.
- *Moyamo* and *Daum* are Korean-based apps that have plant identification features. Find a reliable plant identification app in your language! *PlantNet* works as a free option in the English language.



Screenshots from PlantNet illustrating the plant identification process: identification by plant part (left) and resulting output of identified species with corresponding percentage accuracy (right)



b. Labelling and preparing for seed collection

Students created plant labels in the school's makerspace and prepared the necessary materials for collecting seeds for submission to the Baekdudaegan Seed Vault.

The guidelines followed can be found in the *Field Manual for Wild Plant Seed Collection* published by the National Baekdudaegan Arboretum.



Pedagogical considerations

The activity was guided to help students recognise the assigned plant, not merely as an object of study but as a life form that the students were responsible for protecting. By engaging in this investigation, students fostered an emotional and ethical connection with the plant as their focus and contribution towards plant/seed conservation.

Lesson 7
Seed harvesting and vault submission

Key inquiry question:

HOW CAN OUR SMALL ACT OF COLLECTING SEEDS TODAY MAKE A DIFFERENCE FOR FUTURE GENERATIONS?

Materials used:

- Seed collection kits (including tools for harvesting, sorting, and packaging seeds)
- Reflection worksheet for photo documentation and note-taking during the activity



Tip

Guide students to prepare questions before meeting with seed conservation experts, so they can engage meaningfully during the session.

a. Expert lecture: Seed Vault and conservation practices

Before collecting seeds from plants on campus, students attended a special lecture delivered by staff from the Baekdudaegan Seed Vault.

The lecture provided practical insights into the importance of seed conservation, the mission and operation of seed vaults, and the scientific procedures involved in seed collection.

Through this session, students gained a realistic understanding of conservation work and its value. They came to see that the upcoming seed collection activity was not just a school experience, but a practical contribution to biodiversity preservation in their country.

b. Seed collection from plants on campus

Students collected seeds from the plants assigned to them, using the knowledge and techniques introduced in the expert lecture. During the collection process, they followed appropriate procedures for the selection and handling processes, such as hygiene maintenance, drying, and labelling under the supervision of staff from the seed vault organisation.

c. Packaging seeds for donation

Students packaged the collected seeds using seed bags or black boxes, preparing them for donation to the Seed Vault. By being an active participant in the Seed Hands Project, students saw the selection, collection, and packaging processes from start to finish. This final step reinforced their journey and efforts in contributing meaningfully towards the long-term conservation efforts in their country.

Steps for seed collection

Field collection tools: Seed collection net/bag, digging trowel, transplanting trowel, pruning shears, pole pruners

- 01 Identify target plant species using key features, identification keys and/or an expert.
- 02 Check seed maturity status to ensure that seeds are collected close to the natural dispersal time.
- 03 Assess seed quality by performing a cut-test to check the internal condition of seeds.

Seed cleaning and selection

Seed cleaning and selection involves isolating only viable seeds to enhance their long-term storage efficiency and reproduction potential.

- 01 Check seed maturity and soundness by assessing if the seed moisture content is suitable for the cleaning/selection process.
- 02 Use the appropriate equipment and tools to handle, clean, and examine materials.

Typical methods of seed collection



Collecting with pole pruners



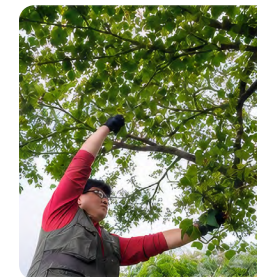
Collecting via seed traps



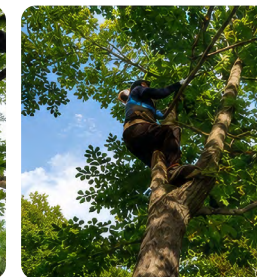
Shaking onto groundsheet



Ground collection



Shaking trees



Tree climbing



Collecting with pruning shears



Hand-stripping seeds

Lesson 8
Promoting seed conservation and awareness

Key inquiry question:

HOW CAN WE MOTIVATE SOCIETY TO PROTECT SEEDS TOGETHER — AND WHAT CHANGES MIGHT OUR IDEAS INSPIRE?

Materials used:

- Exhibition planning template to support organisation of space, sequence, and content of presentations
- Examples of promotional materials and guidance for using design tools like Canva to help students develop and design their projects
- Post-it notes for peer feedback and visitor comments

Students explored the idea of “Seed Savings,” which transformed seed preservation from a task exclusive to scientists into a practice that anyone could take part in.

a. The “Seed Savings” Proposal

Students planned a “Seed Savings” proposal that emphasised the value of biodiversity conservation. They developed visual promotional materials such as leaflets and posters to communicate the concept effectively.

The “Seed Savings” proposal included:



b. Creating a “Seed Savings” leaflet

Students created public-facing visual materials to promote their “Seed Savings” proposal, using formats such as videos, websites, or QR codes. They used design tools like Canva or Google Slides to structure the content clearly and effectively, ensuring the message of biodiversity conservation and the key features of their proposal are well communicated.

Through this activity, students demonstrated how this approach could also serve as an effective strategy for securing and collecting a diverse range of seeds more quickly through collaborative efforts.



Seedream Conceptual Intent
Intention?



• Scientific Background

The Intergovernmental Panel on Climate Change (IPCC) under the United Nations reports that if greenhouse gas emissions continue at the current level, sea level could rise by up to 2 meters by 2100. For example, in the Maldives in the Indian Ocean, about 80% of the land lies less than 1 meter above sea level, so a 2-meter rise would submerge most of the country.

• Importance of biodiversity and its impact on the environment and humanity

Biodiversity in countries at risk of submergence is essential for keeping food systems and ecosystems resilient even as land disappears under rising seas. If native crop varieties and wild relatives are lost underwater, local communities struggle to secure food and adapt to rapid environmental change. By conserving seeds in advance through structured seed-saving schemes, these countries can protect unique genetic resources and later restore local crops and ecosystems after flooding.

• Meaning of “No Maturity” (Open-Ended Savings)

A “no maturity” savings account has no fixed maturity date, so deposits can be made freely and withdrawals are possible at any time. → In the context of a government-in-exile or similar crisis, this means seeds can be withdrawn at the desired time when they are needed. A “no maturity” seed savings scheme allows continuous accumulation, enabling financial resources to be secured before a disaster occurs. These resources can then be used not only for recovery from flood damage, but also for ecosystem restoration projects.

• Key Design Considerations in the Proposal

We conducted a detailed investigation into countries at risk of submergence, including the projected progression of inundation and the rate of reduction in habitable land, in order to design a plan that is as realistic and feasible as possible. Contribution amounts are set according to each country's GDP, taking into account economic differences between nations when designing the scheme.

Examples of students’ work, detailing their “Seed Savings” plan and design considerations

Pedagogical considerations

- The teacher introduced basic financial concepts such as savings with concrete examples to explain how they related to seed preservation. By having a clear understanding of this analogy, students could better translate their knowledge into their proposals for greater public engagement in seed preservation and conservation.
- As the exhibition space was open to the public, its layout was carefully considered for broader engagement and greater impact. Activities for collecting feedback were also planned to encourage meaningful interaction between students and the wider public.

iii. Challenges and solutions in lesson implementation

Challenge	Potential solution
<p>1. Loss of student focus</p> <p>As the project will span multiple weeks and involves several phases — from research and analysis to fieldwork and proposal design — it can be challenging for all learners to remain motivated. Without adequate support, students may disconnect from the overarching goals of the project, treating each activity as an isolated task rather than as a holistic experience.</p>	<p>To address this, periodic goal-reflection checkpoints can be implemented in each phase. These checkpoints allow students to revisit the project’s objectives, evaluate their progress, and set clear, short-term actionable targets. For example, Ms Minju would start each lesson with a 2-minute “goal recall” where students describe how the day’s lesson links to the final outcome.</p> <p>Visible project timelines and milestone boards like a Gantt chart or Kanban board can also be used as a reminder of the bigger picture.</p> <p>Students can be additionally invited to (1) update the progress boards themselves and (2) be rotationally assigned as “motivation leader” to summarise the project status at the end of each week to sustain their engagement.</p>
<p>2. Over-emphasis on technical aspects</p> <p>Given the strong emphasis on scientific and technical competencies, there is a tendency for the project to skew heavily toward STEM-focused outputs, potentially overlooking equally critical socio-cultural and creative dimensions of the learning experience. This imbalance risks reducing the holistic, interdisciplinary nature of the Seed Hands Project, which relies on integrating Science, Technology, Engineering, and Mathematics with social understanding and communication skills.</p>	<p>To mitigate this, heterogeneous teams can be intentionally formed by mixing students with varying strengths across the STEM fields, arts, and humanities disciplines. This ensures that multiple perspectives are brought into each task, allowing students to approach problems through both analytical and creative lenses. For example, students may be invited to present an idea outside of their primary expertise, prompting them to think more critically.</p> <p>Structured team roles (e.g., data analyst, community liaison, design lead) can also be introduced so that non-STEM contributions are valued equally in the process, reinforcing the integrative spirit of the project. Creative outputs can also be encouraged in the form of posters, videos, and infographics, where appropriate.</p>

Challenge	Potential solution
<p>3. Complex interdisciplinary demands for the individual</p> <p>Some tasks within the Seed Hands Project, such as the “Seed Savings” proposal design or scenario analysis using SSP data can be complex for individual students to manage effectively. The scope and interdisciplinary demands of these activities require not only content knowledge but also project management and problem-solving skills, which can be overwhelming for a single learner to handle alone.</p>	<p>Large complex tasks can be broken down into smaller, manageable components, with responsibilities clearly communicated and distributed among team members to encourage collaborative problem solving.</p> <p>This division of labour using tools such as a shared project management board (e.g., Trello or Notion) allows students to focus on specific aspects while still contributing to the overall outcome. Regular collaboration sessions and peer feedback rounds with rotating team leads when embedded in the schedule can foster shared ownership of the project and leverage on the diverse expertise within each group.</p>



Author’s reflections

The Seed Hands Project was an authentic platform for students to experience the interconnectedness of Science, Technology, Engineering, and Mathematics with societal and environmental responsibilities. Across its multi-phase design — from global biodiversity research to the tangible act of depositing seeds in the Baekdudaegan Global Seed Vault — students could see themselves as contributing to a national and international network of conservation.

The long-term nature of the project was both a challenge and a strength. Maintaining student motivation over several weeks requires intentional scaffolding, milestone check-ins, and visible progress tracking. Yet, this extended engagement allowed for deeper learning and a genuine sense of accomplishment at the project’s conclusion. The final exhibition, attended by peers and external visitors, was a demonstration of students’ pride in their work and their capacity to communicate scientific concepts in accessible, persuasive ways.

Ultimately, this lesson reaffirmed my belief in changemaker education — where students were not just recipients of knowledge but agents of sustainable action. The Seed Hands Project creates a learning space where academic rigour, creative problem-solving, and global citizenship can coexist, providing students with a powerful model for how education can respond to the urgent environmental challenges of our time.

Ms Kim Minju

Repurposing Agricultural Waste to Abate Air Pollution

Ms Ratchatha Netthip & Ms Sooprawee Wuttisawat



INSTITUTIONAL PROFILE

Starfish School

LOCATION

Chiang Mai, Thailand

TYPE OF INSTITUTION

Private early childhood and primary school

LESSON DETAILS

NUMBER OF LESSONS

5 lessons

DURATION

360–420 mins

GRADE LEVEL

Grade 5

SUBJECT/ DISCIPLINE

Environmental Science,
Design Thinking

NO. OF STUDENTS/ PARTICIPANTS

232 students
(13 students per class)

STUDENT READINESS

Mixed ability

In the rural agricultural heartland of Chiang Mai, Thailand, the end of harvest season is marked by rice straw burning, which contributes to the air pollution crisis that impacts the health of their community. In this chapter, we learn how Grade 5 students at Starfish School moved through the EDICRA (Explore, Define, Investigate, Create, Reflect, Act) problem-based learning process to define the burning of agricultural waste as a core problem, and design rice straw briquettes and plant pots as solutions to reducing open field burning. We see how the learning framework can act as a scaffold for Grade 5 learners, to shift from passive observers to active contributors that promote a more sustainable future for their community.

In this chapter, we learn:

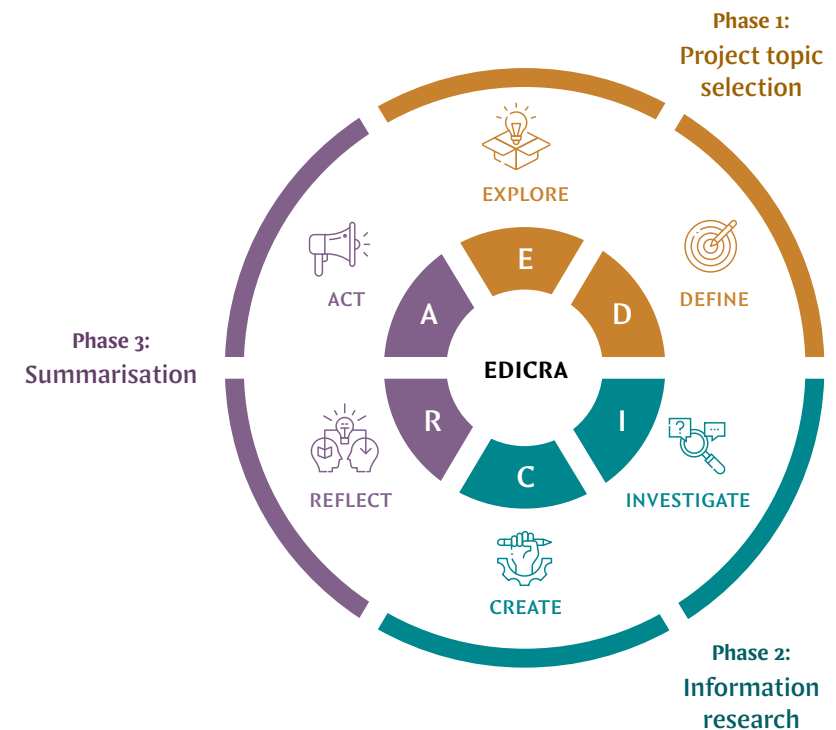
- ✓ How to apply the EDICRA framework to design a problem-based STEM learning module for primary school
- ✓ How observations in their community can help students connect with and drive actionable solutions that improve air quality and promote alternative uses for agricultural waste
- ✓ How to repurpose agricultural waste into reusable solutions for the community
- ✓ Specific steps to create rice straw briquettes and biodegradable plant pots using rice straw

EDICRA is an instructional framework designed to promote student self-directed learning as they develop systematic working habits, plan and manage their time, and engage in hands-on activities that facilitate knowledge construction. The framework was developed by Dr Nanthaporn Janchalia Seributra, Chief Executive Officer of the Starfish Education Foundation, for both early childhood and primary school learning contexts.

This chapter details how the EDICRA learning framework was applied at Starfish School at the primary level. In contrast to the three-stage framework for early childhood STEM education, the framework for primary school comprises six stages (Explore, Define, Investigate, Create, Reflect, and Act).



Rice straw and stubble are often burned in fields to clear land for the next crop



The EDICRA Learning Framework

By Dr Nanthaporn Prae Seributra,
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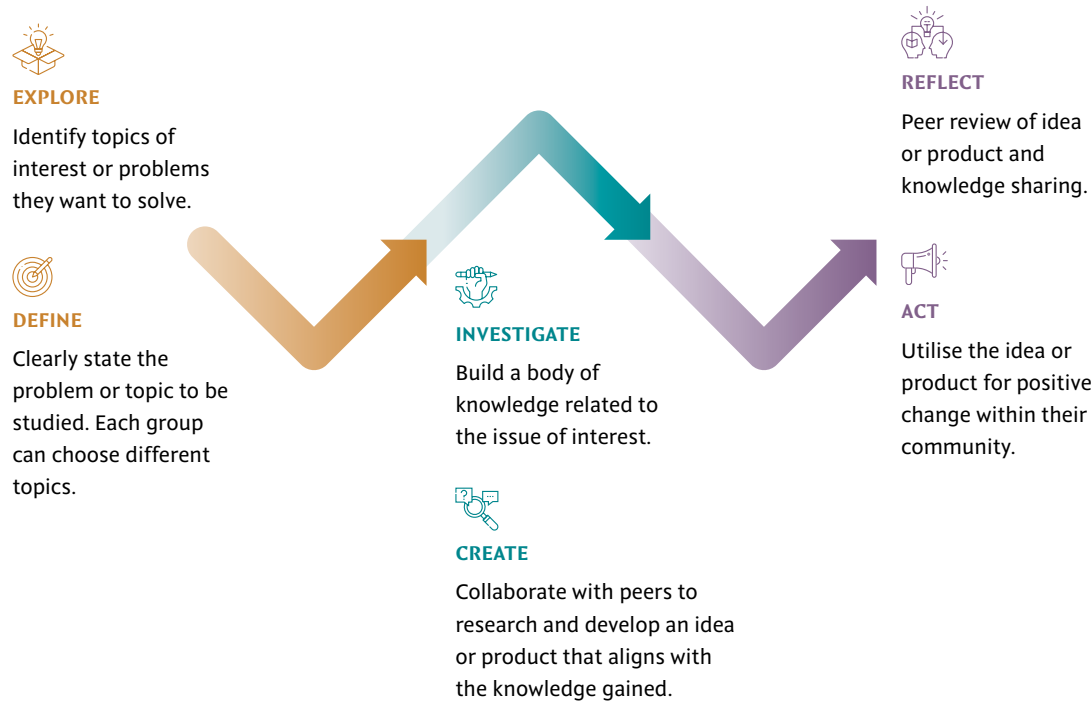
Read more about the EDICRA learning framework in chapter 1.3, and how the framework is applied in an early childhood context in 2.1!

The framework was implemented over a 20-week semester, according to the following schedule:

Level	Subject	Hours/week
Primary	Thai language	3
	Mathematics	3
	English	3
	Science	2
	PBL (Project-based Learning)	4
	Makerspace	3
	Activities/ Sports/ Play	5

Number of weeks spent on each problem-based learning process in a semester:

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Primary	E	D	I				C				R	A								



Students moved through the regular Thai primary curriculum with the opportunity to dive deeper into topics of interest in the PBL-specific subject periods. The PBL lessons specifically followed the EDICRA framework, with PBL teachers discussing potential topics and subject areas to explore in Professional Learning Community (PLC) meetings with other teachers before the semester. These meetings helped identify potential connections between the topics to be covered across subjects, surface a list of possible topics for PBL exploration, and review how project evaluation and assessment can be conducted.

By moving through the EDICRA-guided PBL phases, students were able to dive deeper into topics of interest, identify a theme and project they wish to explore, and work towards an innovative output for their community by the end of the semester. Students were also responsible for managing their time to complete all stages of the EDICRA process within a single semester.

In this chapter, we follow a group of students as they identify **air pollution caused by the burning of agricultural waste** as their topic of inquiry in their PBL sessions. We learn about how the problem affects Thailand's agricultural communities after harvest season, and how practical solutions to repurpose and reduce agricultural waste are appropriate for their community.

Topics covered in this semester	
Solving air pollution caused by burning agricultural waste	
Science	<ul style="list-style-type: none"> Composition of smoke and role of particulate matter Air pollution and human health (PM 2.5) Thermal inversion
Technology	<ul style="list-style-type: none"> Function, operation, and mechanism(s) of air purifiers
Mathematics	<ul style="list-style-type: none"> Data tracking and mapping (e.g., daily AQI levels and distance of smoke travel)
Makerspace	<ul style="list-style-type: none"> Designing and repurposing rice straw into a (biodegradable) product for community use
Languages	<ul style="list-style-type: none"> Translation of scientific concepts using persuasive language for raising social awareness and impact
Sports and play	<ul style="list-style-type: none"> Understanding the limitations and health hazards of engaging in physical activity in PM 2.5 air pollution

Air pollution caused by burning agricultural waste

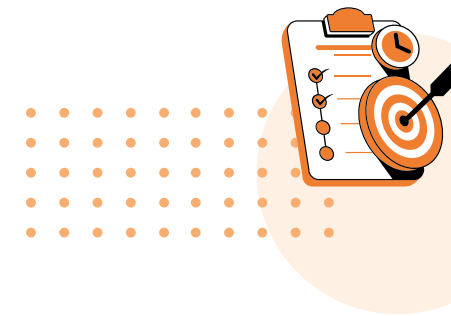
During a community survey, students observed that large amounts of rice straw and stubble were left in the fields following harvest. Most farmers choose to burn them because it is an easy, fast, and cost-free method of waste elimination. When many agricultural areas are burned at the same time, thick smoke covers the sky, contributing to PM 2.5 pollution, which is harmful to human health. Burning agricultural waste leads to smog, toxic air, and increased predisposition to respiratory illnesses, especially among children and the elderly. Although burning is legally prohibited in Thailand, many farmers are unaware of alternative solutions or cannot afford better waste management methods.

To solve this problem, students proposed two alternative methods to repurpose agricultural waste: (1) turning rice straw into charcoal and (2) using it to make flowerpots.



Thick seasonal smog in Chiang Mai exposes residents to unhealthy air and long-term health risks




Flip to Chapter 3.4 to see another way air pollution is understood and tackled using data modelling and campaign ideation!






Curriculum plan

Designing agricultural waste management solutions through a semester of problem-based learning

i. Desired learning outcomes and objectives

Desired learning outcomes	Rationale
 <p>1. Explore and select topics of interest relevant to the community</p> <p>Students explore and select topics by identifying issues or projects of interest by observing their community or environment. They choose a problem relevant to their local context, explain the broader impact (social, environmental, or economic) on the community, and support their ideas with basic research.</p>	<p>Students engage in problem-based learning centred on a problem relevant to their lived experiences. This drives their own learning as they can empathise with the problem at a personal level and collaborate to identify knowledge gaps, conduct research, and ideate solutions that can affect their daily lives.</p>
 <p>2. Define, inquire about, and analyse the problem</p> <p>Students clearly articulate the problem they wish to explore, analyse its root causes using publicly available data, and evaluate its impact on their community from multiple perspectives.</p>	<p>Students engage in self-directed inquiry as they conduct their research, critically analyse, and evaluate the selected problem and its existing solutions. Evaluation from multiple perspectives allows students to understand the broader social and environmental impact of air pollution on their community.</p>
 <p>3. Research, verify, and evaluate accuracy and relevance of information</p> <p>Students gather information from sources such as the internet, books, and community interviews. They evaluate the credibility, accuracy, and congruency of the information obtained from various sources.</p>	<p>Students develop their critical thinking and information literacy skills by evaluating, questioning, and making objective decisions on information from various sources against real-world data.</p>

Desired learning outcomes	Rationale
 <p>4. Modify existing ideas and create products for implementation in their community</p> <p>Students contribute to their community by designing and developing products that repurpose agricultural waste and are useful to their community.</p>	<p>As students collaborate to choose and develop their solutions, this can foster a deeper sense of community and social responsibility. Students are encouraged to be open to diverse ideas and opinions and to work as a collective during the ideation process. For example, students decide on the materials or tools used to create their product and objectively identify their strengths and limitations as a group.</p>
 <p>5. Iteratively reflect and improve ideas</p> <p>Students reflect on their product, identifying areas of success and improvement.</p>	<p>Students engage in the design thinking process as they ideate, plan, produce, and evaluate their product. Evaluations are based on criteria such as long-term sustainability and overall impact of the solution on the community. Students then return to the drawing board to refine their solutions. This reflection and improvement process gives students insight into the iterative process of product development.</p>
 <p>6. Clear communication of ideas through various modalities</p> <p>Students present their product in various formats to members of their community.</p>	<p>Presentations are made through an exhibition or online platforms. Students use tools such as slideshows, videos, or demonstrations to communicate the core ideas and significance of their product.</p>

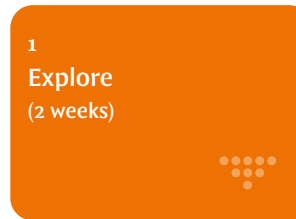
Pedagogical considerations

Encourage inquiry-driven and self-directed learning by tapping on areas of students' personal interest. Structured guidance to identify or knowledge gaps, review systematic evidence-based investigation and engage in critical thinking may be required to support students' learning at earlier stages of the module.



ii. Carrying out the curriculum

Over 20 weeks, students moved through different stages of the EDICRA framework during the PBL lessons, which were led separately from their regular, subject-specific curriculum. This chapter follows one student group as they explored the environmental challenge of air pollution, and devised solutions to reduce the impact and frequency of burning agricultural waste in their community.



The aim of this stage was to identify different areas of interest and to prompt students to start thinking more critically about issues they had surfaced through question prompts from their teacher.

Prompts included:

- From your observations of your surroundings, what makes you feel uncomfortable? Do these observations impact you and those around you?
- What is the one thing you would most like to change, and why?
- If these observations/issues could be improved or solved, would it lead to a better quality of life? How?



During the Explore stage, students were introduced to a range of real-world environmental issues. Students first worked individually and identified personal topics of interest. They were then grouped with peers who shared similar interests, and collaboratively brainstormed to refine and agree on a project topic that encompassed the interests of all group members.

The student group featured in this chapter focused on the impact of burning rice straw and its contribution to PM_{2.5} air pollution.

Other topics students explored included:

- Hypertension: The Silent Threat That Should Not Be Overlooked
- How Should You Handle a Friend's Body Odour?

Student groups engaged in various instructional activities which included viewing multimedia resources, classroom discussions, and sharing of personal or community experiences. Students also brainstormed to identify the causes and consequences of rice straw burning and participated in reflective writing tasks to articulate their initial thoughts and perspectives.

For this group, they were also encouraged to research on the environmental and socioeconomic impact of burning rice straw on seasonal air pollution.



Lesson resources

Some of the Thai resources that students discovered and were guided to consult include:

-  **Rice straw:** A valuable and useful resource readily available
-  **Rice straw and its benefits**
-  **Reduce the burning of rice straw, stubble, and agricultural waste**

Teachers guided students in selecting reliable and credible sources of information to help them deconstruct complex terminology and concepts.

Each group presented weekly updates on their project during class discussions.

2
Define
(2 weeks)

Students were given autonomy to select, define their problem of interest, and deep dive into its causes and implications on the community. As many students from Starfish School live in rural agricultural settings with limited resources for development, students (1) prioritised issues that directly impacted their daily lives and living conditions, and (2) developed practical solutions appropriate and specifically for their community's context.

Students were tasked to:

- Define their chosen problem
- Assess and describe their prior knowledge on the problem
- Identify what they would like to learn more about
- Have a teacher review their research and identify additional knowledge gaps that need to be addressed

Students collaboratively formulated the driving question and defined the core problem of their project. An example is provided below.

Addressing air pollution caused by burning agricultural waste



Students also began to apply basic logical reasoning to assess the feasibility of potential solutions. Various problem-specific ideas were suggested and shared in preliminary presentations that demonstrated their thought processes and articulated the core issue they settled on with the class. For the featured group of students, they prioritised the problem of air pollution caused by the burning of agricultural waste, a critical environmental challenge that drew on their lived experiences and affected their community's health and wellbeing. They ideated solutions that would produce useful or valuable products from agricultural waste.

3 Investigate (6 weeks)

In this stage, students focused on building their knowledge on the chosen problem. Activities involved literature review, note-taking, and the creation of mind maps to organise knowledge. Where applicable, community-based learning such as interviews with local experts was encouraged. Guidance was provided by the teacher only when needed to ensure comprehensive understanding of the issue to support the solution ideation and development processes.

For this group, they built their knowledge by collecting information on the following key topics:

- Biomass energy
- Combustion processes
- Alternatives to burning rice straw to eliminate waste during the planting and harvesting seasons, as well as throughout the agricultural cycle
- The culture, way of life, traditions, and living conditions of people in the community in relation to agriculture production

Throughout the investigation, students documented their research thoroughly. Upon comprehensive understanding of the issue at hand, students collected and analysed data to identify suitable products and approaches to address the problem.



Students presenting their ideas to the class



Example of students' mind map

As part of investigating which solutions had potential, the students also conducted preliminary experiments with different materials and binding agents to test-make charcoal briquettes and flower pots as appropriate solutions for repurposing rice straw. They recorded their observations and data systematically. Experimentation with different materials and binding agents helped students determine which binders were best for maintaining the structural integrity of the briquettes, the optimal time for drying the briquettes, and the balance between burning duration and heat output.

Here, students focused on creating the solution to the problem they identified.

a. Video documentation

Students were tasked to keep video recordings of their design and prototyping process, which were edited and shown to parents and external stakeholders at the final project presentation, with the purpose of:

- Deepening audience understanding of the problem-solving and solution design process
- Allowing teachers to document student progress, collect data, record evidence of student learning, and summarise the learning outcomes

iPads were provided by the school to support documentation of this process. Students filmed and edited their video to showcase how they created their proposed solution. They were free to use any appropriate online video editing software such as CapCut, VLLO, Canva, or iMovie, with the teacher checking on the accuracy and relevance of the content before the final file was exported.

b. Ideation

To tackle their problem of PM 2.5 air pollution caused by burning of agricultural waste, the students generated multiple ideas for utilising rice straw, as it is a commonly burned agricultural waste product.

Each idea was evaluated based on:

- Availability of materials
- Feasibility for production within the school context
- Potential environmental and economic benefits

Through discussion and teacher facilitation, two most viable solutions were selected for further development:



Charcoal briquettes — transforming rice straw into an alternative energy source



Biodegradable plant pots — converting rice straw into eco-friendly planting containers

These solutions emerged from students' recognition of the abundance and lack of utility of rice straw available after harvest and local needs. In particular, students noted the need for (1) affordable fuel alternatives, (2) sustainable agricultural materials, and (3) reducing open field burning.

c. Solution design: Rice straw briquettes

Rice straw briquettes can be used as an alternative household fuel for cooking, replacing traditional sources of energy, such as charcoal and firewood, that are a major driver of deforestation. They are particularly suitable for community-level applications due to their low cost, accessibility of raw materials, and importantly, as a more environmentally sustainable alternative to open-field burning. Students therefore shortlisted this as a possible solution for reducing the amount of rice straw to be burned in the fields.

To support their design process, students conducted online research using various digital resources. They explored relevant information on rice straw utilisation, briquette production techniques, and biodegradable material fabrication. The information gathered was critically reviewed and adapted to suit their local context and available resources.



Cooking with charcoal is deeply rooted in Chiang Mai's culinary traditions

Following the research phase, students applied a “learning by doing” approach by attempting to replicate and modify the methods they had studied. Through hands-on experimentation, they tested different techniques, observed and compared outcomes, and refined their techniques and/or procedures to produce briquettes that could support community energy needs. This iterative practice enabled them to develop practical solutions while deepening their understanding of concepts, such as the role of thermal energy, the physical properties of materials, and the impact on adhesion, density, and evaporation.

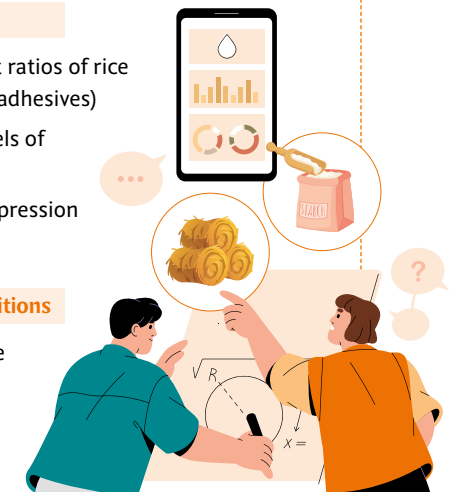
To derive the ideal procedure and composition for rice straw briquettes, students conducted:

Experiments on briquette composition

- To investigate structural integrity using different ratios of rice straw and binding agents (e.g., starch or natural adhesives)
- To investigate the balance between different levels of moisture content and energy output
- To investigate the effectiveness of different compression techniques using simple moulds

Combustion tests on different briquette compositions

- To investigate the relationship between briquette composition, burning duration, and heat output
- To investigate how different levels of moisture contribute to smoke emission



The steps below summarise the prototyping and testing process of their rice briquette:

1

Cut the rice straw into small pieces



4

Blend the boiled rice straw for 1–2 minutes



2

Soak the rice straw in water overnight



5

Crush some charcoal into fine powder and mix it with the blended rice straw



3

Put the straw into the boiling pot to soften it



6

Compress the straw-charcoal mixture into the desired shape



7

Dry the finished compressed charcoal briquettes in direct sunlight for 2–3 days, or until completely dry



8

Test the briquettes by burning them

Students weighed and recorded the ideal proportions in grams and kilograms to ensure a consistent formula across batches. They proposed that a high-quality rice straw briquette should exhibit the following characteristics:

Quality control checklist for rice straw charcoal briquettes

- 1. Structural integrity**
Firm and compact, not brittle or easily broken

- 2. Low moisture content**
The briquette is dry enough for easy combustion

- 3. Efficient combustion**
Long burning duration with consistent heat output

- 4. Minimal smoke production**
This indicates cleaner burning

- 5. Uniform shape and size**
This ensures consistent performance across briquettes

After conducting further research and experimentation, students established the following composition and procedural specifications:

Material proportions

- 3 parts rice straw : 1 part charcoal powder
- Combine with a natural binder like starch (5–10% of total mixture by weight)
- Approximately 1–2.5 litres of water per 5 kilograms of rice straw for making briquettes

Processing time

- Preparation (shredding, mixing, moulding) requires 1–2 hours
- Briquettes require 2–3 days of indirect sun (or being placed in a drying area), to reduce moisture content for efficient burning

The teacher's role was to facilitate and guide the process by providing support in evaluating the resources used, ensuring safety precautions were taken, and encouraging reflective thinking, while allowing students to take ownership over their learning and the decision-making.

Tips

Support iterative learning by encouraging students to:

- Learn from trial and error
- Reflect on unsuccessful attempts
- Continuously refine their designs

Connect learning to real-world contexts by:

- Encouraging students to consider and tailor solutions to local needs
- Highlighting the potential for sustainable, real-life implementation and small-scale production

d. Solutions design: Biodegradable plant pots

Lastly, students shortlisted a second solution to create **biodegradable plant pots** using rice straw, as an added sustainable alternative to the traditional practice of burning agricultural waste. This was shortlisted as an appropriate community-friendly solution and another cost-effective and practical alternative to increase the uses of rice straw.



Biodegradable plant pots naturally decompose in the soil, eliminating long-term waste and microplastic pollution

Students conducted pilot experiments by:

- Testing different methods of shredding and processing rice straw, to determine ease of coating with natural adhesives and moulding
- Combining straw with different natural binders (e.g., starch paste) to test for durability and water resistance
- Using different moulding techniques to shape durable pots that have uniform wall density for structural integrity

Materials required

- Rice straw: 60g
- Paper pulp: 20g
- Tapioca starch: 20g
- Water: 120–150ml
- Caustic soda (2–3 tablespoons)

Natural binders

- Tapioca starch (most commonly used)
- Rice flour
- Cornstarch
- Ground sticky rice

Shredding and processing

- Cut the straw into 0.5–2cm pieces
- Soak in water until softened (12–24 hours)
- Blend or grind thoroughly until pieces are 0.5cm or smaller
- Dry for 2–4 days under sunlight or for 4–6 hours in an oven

Final weight

- Before drying: 200–250g per piece
- After drying: 95–125g per piece

Moulding technique

- Chop or grind the materials into small pieces
- Mix all ingredients thoroughly
- Compress the mixture into a mould by hand or using a press
- Thickness of the rim of the plant pot can range from 0.5–1.5cm

To stretch students' thinking and prompt further support prototype development and inquiry, the teacher posed guiding questions such as: "How can the plant pots be made more durable yet still be biodegradable?"

After further research and preparation, the students finalised the procedure for creating their biodegradable plant pots:

1

Assemble the equipment and materials for making plant pots from rice straw



2

Soak the rice straw in water overnight



3

Cut the soaked rice straw into small pieces





4

Put the chopped rice straw into a pot and boil it

5

Add 2–3 tablespoons of caustic soda to the pot to help soften and break down the rice straw



6

Stir with a wooden spatula for about 20–30 minutes



7

After letting it cool, rinse it with clean water 2–3 times



8

Blend the rice straw for 1–2 minutes until it becomes fine



9

Pour the blended rice straw into a strainer to separate the water





10 Boil the prepared rice straw with 1–2 tablespoons of tapioca starch



11 After that, place the mixed rice straw into a mould of your desired shape



12 Leave it to dry in the sun for about 1–2 days or until completely dry

13 Remove it from the mould, then grow a plant in the rice straw pot



The quality of the plant pots was assessed using the criteria below:



Quality control checklist for biodegradable plant pots

1. Structural strength

- Able to support the weight of soil and seedlings without deformation
- Does not crack or break during handling or transportation
- Maintains its shape for at least 2–4 weeks during the seedling stage

2. Water resistance

- Does not become soggy or deteriorate too quickly under normal watering conditions
- Retains its shape after continuous exposure to water for 5–10 minutes
- Provides good drainage without excessive water retention that may cause mould growth

3. Decomposition rate in soil

- Begins to decompose in soil within 30–45 days
- Decomposes effectively within 60–90 days
- Leaves no harmful residues or materials that could negatively affect soil quality

Pedagogical considerations

The PBL module and framework emphasise iteration and improvement as core parts of the learning process. For example, the student group featured tweaked the techniques and procedures applied over several rounds of testing. Repeated testing and evaluation allowed them to develop more efficient charcoal briquettes and durable plant pots.

Through the development of these two solutions, students demonstrated:

- Localised awareness of the repercussions of traditional farming
- Community-centric responsibility through ideation, problem-solving, critical thinking, and production of sustainable solutions
- Ability to engage in the engineering design thinking process and apply scientific and mathematical knowledge to address real-world challenges

5 Reflect (2 weeks)

After creating and testing their solutions, students reflected on their products.

Reflections from this group included:

- Equipment challenges as they were using a low-powered blender. The blender could not adequately blend all of the straw quickly to accommodate the quantity of straw for more efficient testing and production. They proposed to manually chop the rice straw into smaller pieces before blending the rice straw in smaller batches to achieve finer consistency.
- The importance of building confidence and familiarity with the concepts learnt by offering opportunities to rehearse and incorporate constructive feedback on their presentation skills.

6 Act (2 weeks)

In this final stage students were expected to present their design process and final solutions to the class and implement their solutions within their community.

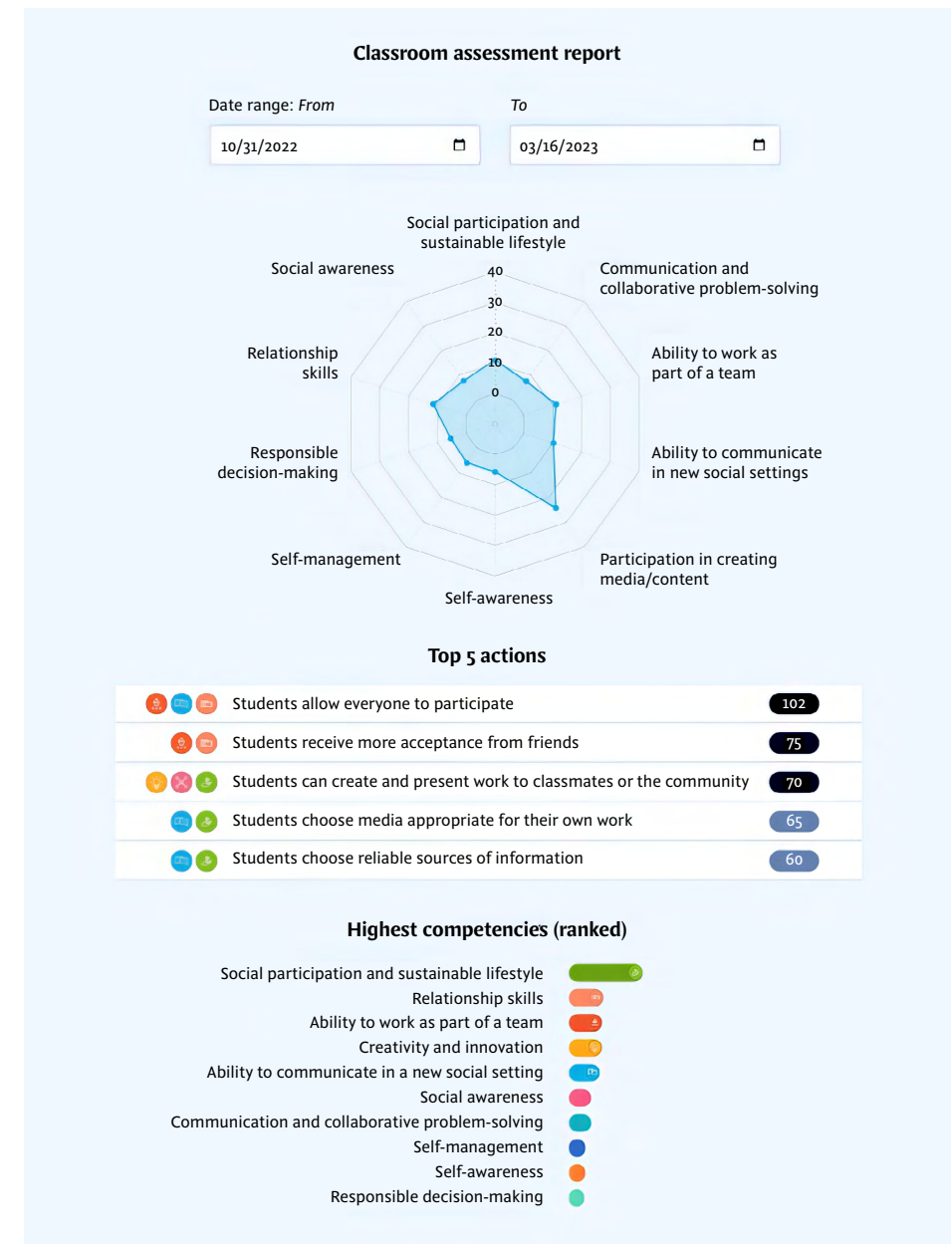
a. Final presentations

While presentations were integrated at multiple stages of the EDICRA process, the primary presentation occurred during this stage. Here, students demonstrated their developed products, explained the production process, and reported their experimental findings to the class.

Presentation preparations included organising content and developing supporting materials such as slides, physical prototypes, and process videos. The students also engaged in group rehearsals to ensure clarity and confidence of their presentation delivery.

Assessment was conducted using the Starfish Class assessment method that supports holistic and continuous development. These assessments included evaluation of product quality, students' learning processes, presentation performance, and self- and peer-assessment.

For the video component, the groups produced a final video documenting their entire learning journey. Feedback on content accuracy, completeness, and clarity were provided for revision prior to final presentation.



Classroom assessment report showing how students' skills have changed over time

b. Community implementation

Students implemented both solutions — rice straw briquettes and biodegradable plant pots — within their local community. The briquettes were used as an alternative household energy source for cooking, helping to reduce reliance on traditional charcoal and minimise open-field burning of rice straw. The biodegradable plant pots were used to grow vegetables for community consumption and ornamental plants to beautify their surroundings, offering an eco-friendly alternative to plastic containers.

The community responded positively by showing interest, adopting the products on a trial basis, and providing constructive feedback regarding performance, such as burning duration of the briquettes, durability of the pots, and ease of use. This feedback was incorporated into subsequent improvements made by the students.

This initiative resulted in a reduction in open-field rice straw burning at the local level, promoted more efficient use of agricultural waste, and enhanced environmental awareness among both students and community members. Furthermore, the project demonstrated potential for further development of rice straw into practical community-based products and as an avenue for small-scale income-generating activities.



iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
1. Differences in students' prior knowledge and skills	Use mixed-ability grouping and differentiated instruction
2. Time constraints for experimentation and production	Develop a clear timeline and offer opportunities to stretch students' learning by extending beyond class time
3. Limited materials and equipment	Use local materials and encourage simple tool design that serves community needs
4. Safety concerns during hands-on activities	Provide close supervision and establish clear safety guidelines
5. Limited skills in analysis and reflection	Use guiding questions and continuous reflection activities to gauge students' understanding



Authors' reflections

The EDICRA process involved students progressing from selecting a problem of interest to creating a product for community use. Students found the investigation stage considerably more challenging as it involved critical analysis of the information obtained from various sources and distinguishing between facts and opinions. In some cases, students failed to summarise key points and instead copied entire sections of content. This required greater support from their teacher to monitor, review, and provide guidance more actively throughout the research process.

For many teachers, this was also a learning journey for them. Many of the problems and solutions developed to address them were areas in which the teachers themselves did not previously have in-depth knowledge. It was therefore particularly inspiring to witness the students' dedication and commitment, as they took ownership of their learning process and actualised their ideas.

Ms Ratchatha Netthip, Ms Sooprawee Wuttisawat

Designing Tidal Early Warning Systems with Micro:bits

Ms Retna Widiyasrini



INSTITUTIONAL PROFILE

Sekolah Menengah Atas Negeri (SMAN) 6 Batam

LOCATION

Air Raja Island, Riau Islands Province, Indonesia

TYPE OF INSTITUTION

Public senior high school

LESSON DETAILS

NUMBER OF LESSONS

5 lessons

DURATION

90 mins / lesson

GRADE LEVEL

Grades 10–12

SUBJECT/ DISCIPLINE

Science, Geography, and Technology

NO. OF STUDENTS/ PARTICIPANTS

30 per class (6 groups of 5)

STUDENT READINESS

Mixed ability

Indonesia is ranked second among the world's most disaster-prone countries. The Riau Islands in particular have become increasingly vulnerable to frequent tidal flooding, causing disruptions to education and daily life. Residents of the Riau Islands, including Batam city, are not well-connected to official disaster monitoring systems, resulting in low awareness of and readiness to respond to flooding.

In this chapter, we understand how a team of teachers at SMAN 6 Batam co-created a hands-on micro:bit lesson to guide students in creating their own Tidal Early Warning Systems (TEWS), for alerting the community when risk of flooding is imminent. The five-lesson module integrates lessons in Geography, micro:bit technology, and coding, to design an interactive problem-solving experience for students and create an output that can be directly used in community disaster mitigation.

In this chapter, we learn:

- ✓ Geography of the Riau Islands and their vulnerability to tidal flooding
- ✓ The mechanics of tidal flooding, Indonesia's disaster management cycle, and disaster warning systems
- ✓ The basics of using micro:bit technology and Grove Inventor Kits
- ✓ How to craft a hands-on lesson using micro:bit technology and Grove Inventor Kits to create Tidal Early Warning Systems for community use

The Riau Islands are a province in Indonesia that comprises over 2,400 islands, with approximately 96% of its territory consisting of maritime space. Its population, economy, and infrastructure are deeply interconnected with the coastal landscape. However, the region has become increasingly susceptible to **tidal flooding**, as a result of a combination of factors such as land subsidence, rising sea levels, and extreme weather patterns, all of which are exacerbated by climate change.

1. <https://nobleasiaid.com/the-birth-of-pancasila/>

Coastal cities such as Batam, situated just 1–3 meters above sea level, face greater vulnerability during monsoon seasons due to increased frequency of high spring tides (also known as king tides) and storm surges. According to Indonesia's Meteorology, Climatology, and Geophysics Agency (BMKG) in 2024, these events had been growing in both intensity and duration, posing a critical threat to local infrastructure and the regional economy. Despite these risks, Batam does not have a Regional Disaster Management Agency. As such, disaster response remains limited to resident vigilance and no formal mitigation measures have been put in place.

In this chapter, we follow five teachers from SMAN 6 Batam to see how they integrated knowledge on Environmental Science and disaster mitigation with micro:bit technology, to design a five-lesson module for grade 11 students to develop a TEWS for their community. This module was designed to (1) address the disconnect between theoretical concepts learnt in Geography and students' lived experiences (coastal reality) and (2) promote Pancasila values (i.e., the five principles transcribed as Indonesia's state philosophy)¹ to foster global citizenship and affect change in their community. These were outputs from a STEM (Digital) Programme in Indonesia, held in partnership with meriSTEM@NIE, National Institute of Education (Singapore) and Pretasi Junior Indonesia (PJI), with support from Temasek Foundation, Caterpillar Foundation, and the Ministry of Education, Culture, Research, and Technology, Indonesia.

Did you know?

A spring tide, popularly referred to as a king tide, occurs during a new and full moon, when the Sun, Moon, and Earth are aligned. This alignment results in the highest tidal ranges in the lunar cycle.



The islands of Batam at sunrise

The teaching team from SMAN 6 Batam consisted of:

Name	Academic title	Subject
Devi Henisa Arniza Sari, S.Pd	Bachelor of Education	English
Ria Irawan, S.Pd	Bachelor of Education	Economics
Nendry Susilo, S.T	Bachelor of Engineering	Entrepreneurship and Informatics
Deddy Karokaro, S.Pd	Bachelor of Education	Geography and Biology
Norizan, S.Pd	Bachelor of Education	Indonesian Language



The SMAN 6 Batam teaching team

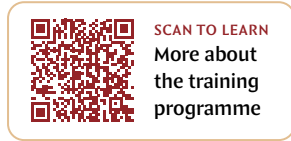
Topics covered in this lesson	
Disaster management	Geography & Environmental Science
<ul style="list-style-type: none"> The disaster management cycle (mitigation, preparedness, response, and recovery) 	<ul style="list-style-type: none"> Tidal flooding (also known colloquially as “rob floods”) in the Riau Islands Coastal geography of the Riau Islands Effect of climate change on rising sea levels Interactions between man and the environment Disaster risk and vulnerability mapping
Applications of technology to detect environmental disasters	Uses and applications of micro:bit
<ul style="list-style-type: none"> Understand weather and environmental monitoring tools Understand how digital tools are used for disaster risk reduction (e.g., early warning systems, flood sensors, and Geographic Information Systems, or GIS, mapping) 	<ul style="list-style-type: none"> Understand the core components and functions of the BBC micro:bit Understand input and output systems in the context of digital sensing Use block-based programming (MakeCode) to apply fundamental coding concepts such as data logic, variables, and control structures Use ultrasonic sensors to measure distance and water level

Designing STEM lesson experiences for disaster mitigation

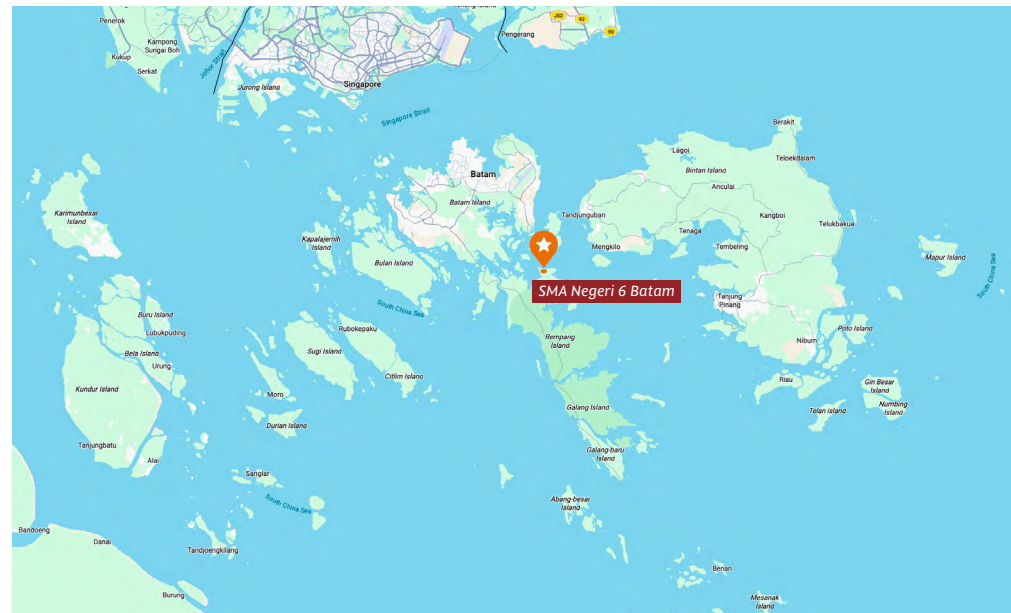
The five-person teaching team attended a year-long STEM capacity building programme for grade 9–12 teachers held in collaboration with meriSTEM@NIE and PJI, to strengthen their ability to implement integrated STEM education in the classroom. The programme was conducted in four phases:

1. Foundational courses on STEM pedagogy and lesson design, with a strong focus on project-based learning and student-centred approaches
2. Hands-on facilitated sessions on using Internet of Things-enabled devices and coding platforms and tools (e.g., Grove Inventor Kits and micro:bit technology)
3. Crafting of integrated STEM lessons to be showcased at a symposium
4. Lesson implementation and feedback through on-site lesson observations

The programme facilitated the integration of Indonesia's Ministry of Education mandate for inclusion of coding and AI in classrooms nationwide. The training cohort produced a combined 32 STEM lessons across high schools in Indonesia's Kepulauan Riau Province and Bogor Regency.



SMAN 6 Batam in Air Raja Island is acutely affected by tidal flooding, and most of its students reside in coastal areas highly susceptible to inundation. While disaster mitigation is a central theme in Grade 11 Geography, this topic has traditionally been taught through conventional, classroom-based methods, offering limited contextual relevance to students' lived experiences and few opportunities for experiential learning. Additionally, subjects are frequently taught in isolation, lacking meaningful interdisciplinary integration.



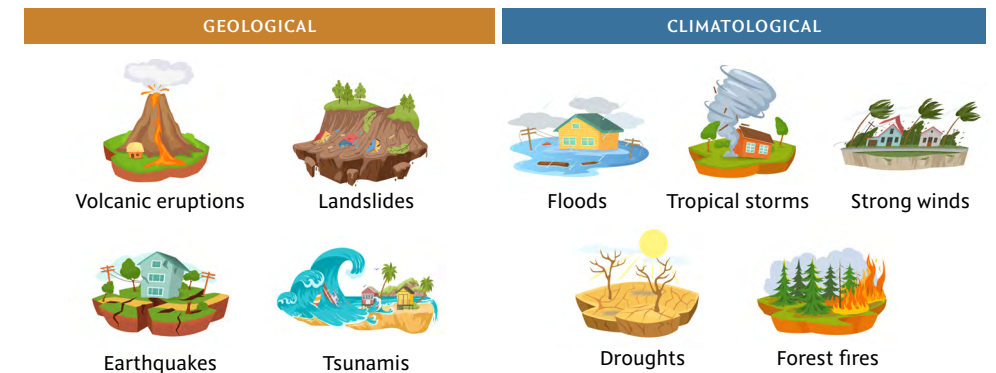
Location of the Riau Islands and SMAN 6 Batam

In this chapter, we examine an integrated STEM micro:bit module facilitated by the SMAN 6 Batam teachers, to create a Tidal Early Warning System (TEWS) — a student-led, interdisciplinary project developed in response to recurring tidal flooding experienced by their community. The sensor-based early warning system was designed using BBC micro:bit to monitor tidal fluctuations and provide timely alerts to residents. This module adopted an interdisciplinary, project-based approach with the Indonesian national framework to foster global citizenship, independent thinking, and proactive problem-solving.

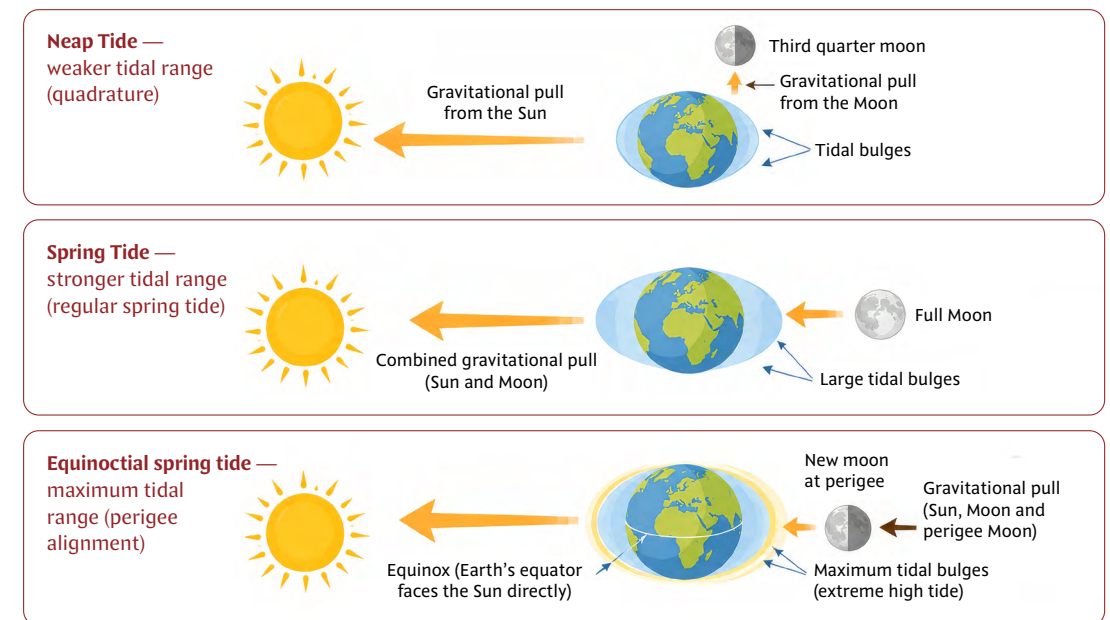
Natural disasters, tidal flooding, and their impact in Indonesia

Ranked second among the world's most disaster-prone countries in the 2024 World Risk Report, Indonesia faces an increasingly severe disaster risk each year. Schooling and education have been particularly affected by the increasing frequency and magnitude of these natural disasters; in 2024 alone, more than 2,000 educational institutions were damaged, causing considerable disruption of learning for students across the country.

Classification of natural disasters in Indonesia



Tidal flooding, known in Indonesia as *banjir rob*, or “rob flood”, occurs when seawater inundates low-lying coastal areas during periods of high or extreme tides. Unlike river flooding caused by upstream rainfall, tidal flooding originates directly from the sea and is driven by the gravitational forces of the moon and the sun on ocean water levels. Its impact can be intensified by storm surges, strong onshore winds, and rising sea levels due to climate change.



How tides are affected by the Sun and Moon



(top) Batam during a rob flood
 (right) Transporting residents on boats during flooding
 (bottom) Residence in Batam during flooding



Geographically, the northern coastal areas of Java, particularly Jakarta, Semarang, and Pekalongan, are most vulnerable to tidal flooding. These areas lie on flat, low-lying delta plains, often at or below sea level. The relatively shallow and semi-enclosed characteristics of these waters amplify tidal ranges, particularly during equinoctial spring tides when the Sun, Earth, and Moon align.

Impact of tidal flooding on the Riau Islands



Coastal erosion has worsened significantly due to the large-scale loss of mangrove ecosystems, primarily driven by land conversion for development. As a result, mangroves are no longer able to function effectively as natural barriers against tidal flooding.



Tidal flooding has inundated hundreds of homes, causing displacement and property loss, while increasing the risk of diseases such as diarrhoea, dengue fever, and skin infections due to contaminated water.



Coastal communities dependent on fisheries, maritime transport, and tourism face recurring losses due to damage to fishing equipment, vessels, and port infrastructure. Industrial areas in Batam are also affected, with flooding disrupting factory operations.

Flood management in the Riau Islands



BMKG meteorologist monitoring weather conditions across Indonesia

BMKG routinely issues early warnings regarding tidal flood risks through both traditional media and digital platforms. For example in April 2026, the BMKG anticipated coastal flooding to occur between 1 and 12 April in several parts of the Riau Islands, coinciding with the full moon on 2 April 2026, which was expected to elevate maximum sea levels between 08:00h and 12:00h.²

Despite continuous early warnings, the effectiveness of these communications in reaching rural populations with restricted access to media and digital platforms remains limited. Although water level monitoring instruments have been installed at several locations, the data generated are primarily accessible only to BMKG, reducing their practical utility for community-level preparedness. This highlights a critical gap in the early warning system, where localised, accessible alert mechanisms such as audible alarms or community-based notification systems are essential. Such systems would significantly enhance local awareness, preparedness, and response capacity in areas that are less connected to formal information channels.

The micro:bit project explored in this chapter aimed to address this gap, guiding students to design an accessible community-based TEWS to increase community awareness and disaster readiness.



2. <https://bpbd.batam.go.id/>



Module plan

Designing a Tidal Early Warning System using micro:bit technology

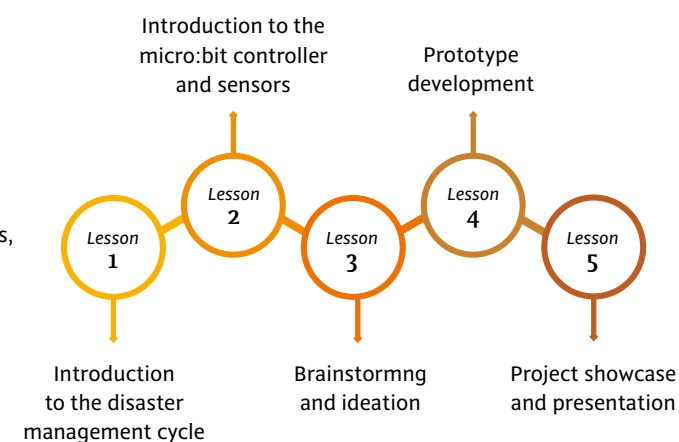
i. Desired learning outcomes and objectives

Learning outcome	Rationale
 <p>1. Knowledge</p> <ul style="list-style-type: none"> Explain the phases of the disaster management cycle (i.e., mitigation, preparedness, response, and recovery) Identify and explain the specific patterns and causes of tidal floods Describe how technology, such as the Internet of Things (IoT), can be used to mitigate the risks of natural disasters 	<p>Disaster management is a mandatory topic within the Geography curriculum. Introducing the concept early helps students understand the diverse disaster risks in Indonesia. Students learn (1) strategies for disaster mitigation, specifically regarding local tidal flooding vulnerabilities, and (2) how technology can be integrated to design meaningful solutions that are responsive to real-world challenges.</p>
 <p>2. Developing 21st-century skills</p> <ul style="list-style-type: none"> Critical thinking: Students analyse and interpret data to identify core issues and appropriate solutions as they propose and evaluate ideas Innovation: Students code micro:bit controllers and sensors to design innovative tidal TEWS Collaboration: Students brainstorm, plan, test, and refine prototypes, solving development challenges as a team Communication: Students clearly articulate their ideas, objectives, and progress to their peers and teacher 	<p>By designing real-world solutions, students cultivate 21st-century skills. Coding and iterative prototyping foster a growth mindset, while providing an authentic context to drive responsive solutions for their community.</p>

Learning outcome	Rationale
 <p>3. Cultural practices, values, ethics, and attitudes</p> <ul style="list-style-type: none"> Community awareness: Understand the lived realities of tidal flooding risks in coastal communities Proactive stewardship: Cultivate a proactive attitude towards environmental stewardship and local disaster preparedness 	<p>By understanding local issues, students develop a sense of community responsibility and citizenship by contributing to local disaster risk reduction.</p>

ii. Carrying out the module

The module spans five lessons, each lasting 90 minutes:



Interactive teaching slides used in each lesson have been linked accordingly in the following sections.



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The full list of teaching slides and worksheets, in both English and Indonesian

Lesson 1
Introduction to the disaster management cycle

Specific instructional objectives

After this lesson, students should be able to:

- ✓ Describe the phases of the disaster management cycle and explain their role in disaster risk reduction
- ✓ Identify and describe common types of natural disasters in Indonesia (with a focus on those affecting coastal communities)
- ✓ Analyse the environmental, social, and economic impacts of common natural disasters in Indonesia (with a focus on those affecting coastal communities)
- ✓ Illustrate the influence of the Sun and Moon on tidal patterns with reference to tidal flooding

Materials required:

For teachers:



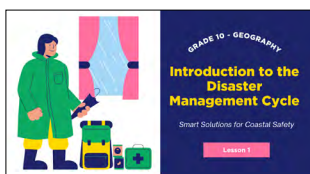
SCAN TO ACCESS

- The disaster management module in the Geography curriculum, in Bahasa Indonesia (Indonesian national curriculum)



SCAN TO ACCESS

- Teaching slides



SCAN TO ACCESS

- The Tide-O-Matic simulation worksheet

For the Tide-O-Matic simulation:

- Earth-Sun card system template (printed in colour if possible, on white card stock or equivalent paper)
- Earth-Moon system template (printed or copied onto a transparency sheet)
- Earth template (printed on white card stock or equivalent paper)
- Scissors
- Two pushpins
- Two small, thin pieces of cork (e.g., a sliced wine cork)
- Optional: cardboard or card stock (at least 12 x 12 in approximately 30 x 30 cm)
- "Rob" flood and tidal pattern worksheet



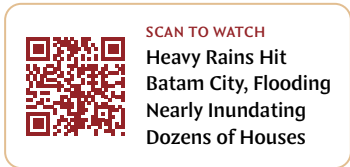
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Instructions and printable materials for the Tide-O-Matic simulation

a. Hook (10 mins)

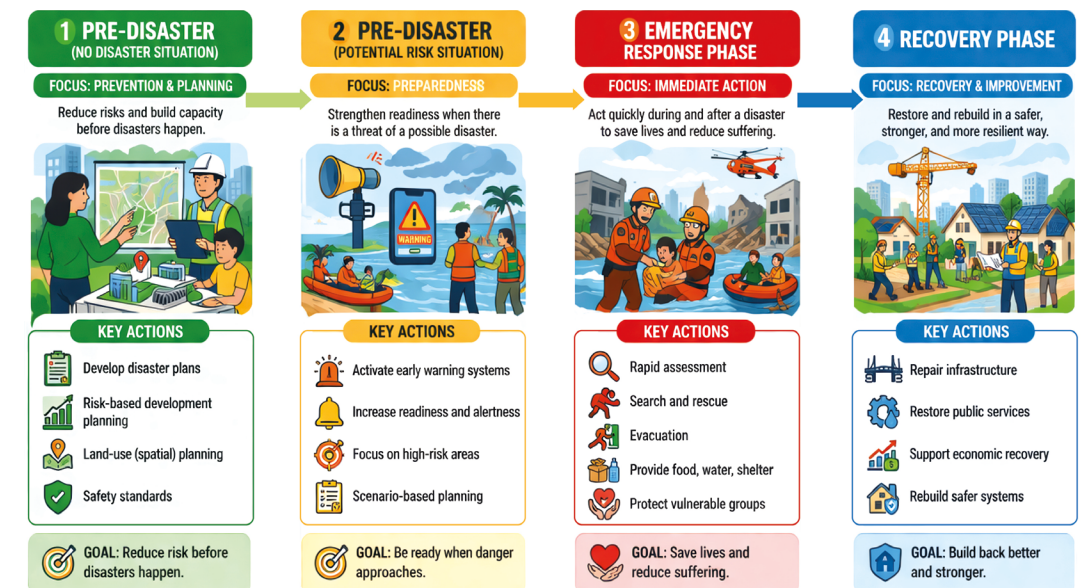
The teacher began the class by showing a short video of recent heavy rain and flooding in Indonesia, with a localised focus on the impact on Batam's residents.

This was followed by asking the class: "What would you do if this happened in your neighbourhood?" and "What types of natural disasters are common in your community?"



b. Lecture (20 mins)

The teacher distinguished between geological natural disasters and climatological natural disasters in Indonesia, and shared details on regional risk zones in the country prior to introducing students to the disaster management cycle. This was followed by an overview of the role of key institutions such as Indonesia's National Disaster Management Agency (BNPB).



Key steps in the disaster management cycle

- Videos/pictures of recent natural disasters in Batam/Indonesia
- Quizzes in Kahoot
- Padlet/Mentimeter for interactive brainstorming

The Meteorology, Climatology, and Geophysical Agency of Riau Provinces consistently issues early warnings through social media, its website, and local news. These updates include weekly forecasts and alerts for potential disasters, such as tidal conditions.

**Do you check these updates?
Are you truly aware of the warnings provided?**



Sea Waters forecast for the Riau Islands Published by BMKG

Reflective questions posed to students, alongside access to data from the Meteorology, Climatology, and Geophysical Agency in Riau Province

c. Hands-on activity: Tide-O-Matic simulation (50 mins)

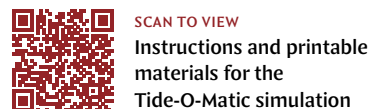
Students were then introduced to “rob floods” and how they impact communities, through a video.

This was followed by a hands-on activity where students formed groups of three and explored, analysed, and identified how the **Tide-O-Matic** simulation models different tidal patterns. The instructions for setting up this activity are linked below.



Did you know?

Tide-O-Matic is a simple model designed by The Exploratorium to help students understand the influence of the Sun and Moon on the ocean tides.



After the simulation, each group had three minutes to share their observations and interpretations with the class. To check on and reinforce students’ understanding, the teacher posed discussion questions to the class and recapped the main takeaways from the activity.

Discussion questions for students

Gauging content knowledge:

- Based on your observations, how many high tides and low tides occur in one day?
- What happens when the Sun, Earth, and Moon are aligned? What type of tide occurs in this position? Why?
- What happens when the Moon forms a 90° angle with the Sun? What type of tide occurs in this situation? Why?
- What is the difference between spring tide and neap tide based on your simulation?
- Which condition produces the highest tides? Why?

Reflecting on their learning:

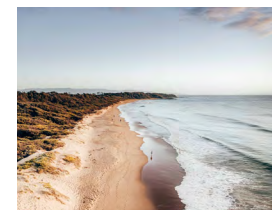
- What is one new concept you learned from this experiment?
- What part of the experiment helped you understand tides the most?

Key takeaways

- The Moon’s gravitational pull is the main cause of ocean tides
- The Sun can affect tides by strengthening or weakening the Moon’s gravitational pull
- Most places experience two high tides and two low tides each day
- Spring tides occur when the Sun, Earth, and Moon align, producing the highest tides
- Neap tides occur when the Sun and Moon are at a 90° angle, producing weaker tides
- The movement of the Earth and Moon changes daily tide time
- Tides can affect coastal areas and cause tidal flooding (*banjir rob*)

d. Reflection and conclusion (10 mins)

Students’ understanding was assessed through an interactive quiz before their teacher concluded the lesson with a one-minute summary on the importance of understanding natural disaster types, and the need for adequate preparation.



What is the main cause of ocean tides?

- A Wind
- B Earth’s rotation
- C The Moon’s gravitational pull
- D Ocean currents

What is the main goal of disaster mitigation?

- A Respond after disasters
- B Reduce disaster risks before they happen
- C Evacuate people during disasters
- D Provide aid after disasters



Sample quiz questions

Pedagogical considerations

- Incorporate news clips, reports, and images of natural disasters in your country or community to activate prior knowledge and empathy.
- Use simulations (e.g., the Tide-O-Matic simulation) to scaffold students' understanding of tidal dynamics. This transforms abstract geographic variables into a hands-on, interactive experience as students model the changing tides.
- Incorporate interactive digital tools such as Padlet and Kahoot to facilitate brainstorming, group sharing, promoting student engagement, and assessing their understanding.
- Use a simple reward system to recognise thoughtful contributions and encourage active participation during class discussion and group tasks.

Lesson 2 Introduction to the BBC micro:bit

Specific instructional objectives

After this lesson, students should be able to:

- ✓ Identify and describe the functions of the BBC micro:bit and grove inventor kit components
- ✓ Programme the BBC micro:bit controller using block-based coding on MakeCode to create simple IoT projects

Materials required:



SCAN TO ACCESS

- Teaching slides
- BBC micro:bit (1 per group)



SCAN TO VIEW

- Grove inventor kit (1 per group)

a. Hook (10 mins)

The teacher began class by showing two short videos on how technology such as drones, sensors, and early warning systems are used in disaster management in Indonesia and globally.

The teacher then asked, "Given the videos you've watched, how can a small device help save lives?" Students were then asked to brainstorm and post their answers on Padlet as part of a class discussion.



SCAN TO WATCH
1950 vs 2019: The Development of Genius Technology From Time to Time



SCAN TO WATCH
Getting to know the Indonesian Tsunami Early Warning System (INATEWS) at BMKG

b. Lecture (20 mins)

Students were introduced to the BBC micro:bit and the grove inventor kit components, key features, and applications, followed by Microsoft MakeCode, the primary coding interface they would engage with.



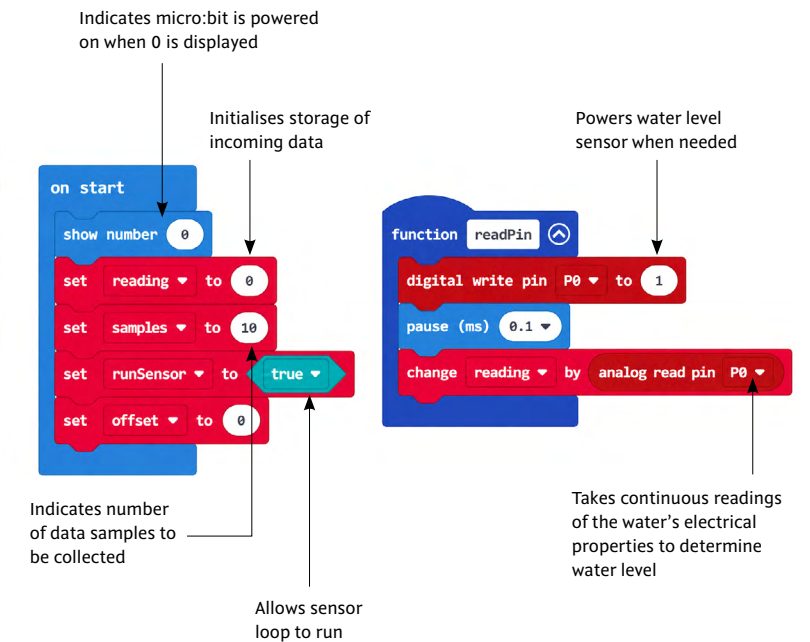
SCAN TO VIEW
Microsoft MakeCode's micro:bit site with resources

Students formed groups of 4–5 for the next task.

c. Hands-on activity (50 mins)

Students were given time to explore the MakeCode micro:bit webpage and experiment with the micro:bit controller and grove inventor kit tools by constructing and testing up to seven simple IoT projects. The projects included making light and temperature measurements, building a water level sensing meter, and a step counter.

The Water Level Sensing Meter project was also prioritised as a key explorative task as it provided the technical foundation for students to design and code their own tide-detection systems. To incentivise progress, the teacher structured the lesson as a competition, rewarding the first group to successfully complete all seven tasks.



Example of a code to determine water level

Adds sensor readings (for a smoother weighted moving average)

Resets reading to zero before each data collection cycle

Start switch for data collection loop

Runs the data collection loop from 0 to the number of samples set (10)

Subtracts the baseline calibration value from the summated readings

Sends final water level to computer when device is connected via USB. Different water levels are represented on the LED screen (i.e., the higher the water level, the more LEDs light up)

Stop switch with X to denote that the system has been turned off

Example of a code to determine water level

d. Reflection and conclusion (10 mins)

To close the lesson, the teacher guided students to reflect on their learning by asking questions such as *“What did you learn about the role of technology in disaster safety management?”* and *“What aspects of programming were easy or challenging for you?”*

Did you know?

Collaborative learning is a core component of Indonesia’s national curriculum, which emphasises student-centered pedagogy to cultivate critical thinking, creativity, communication, and collaboration.

This was followed by a summary of key takeaways from the lesson and highlights of specific technical skills and collaborative behaviours that students demonstrated.

Read more about how micro:bits and ultrasonic sensors are used in a different context in chapter 2.3 of the book!

Pedagogical considerations

- Showcase modern disaster mitigation technologies to ground theoretical concepts in real-world applications and inspire students to innovate their own solutions.
- Encourage paired or small group work to promote peer problem-solving, and use a “gallery walk” approach to monitor progress, pose guiding questions, and provide targeted support.
- Challenge students to extend their project by integrating other sensors or functions to further value add to its purpose. This shifts away from simple procedural execution towards deeper innovation-driven engagement.

Lesson 3
Brainstorming and ideation

Specific instructional objectives

After this lesson, students should be able to:

- Investigate and empathise with the disaster risks faced by vulnerable coastal communities through data collection and contextualised research
- Analyse and evaluate existing TEWS
- Plan, design, and present their group’s TEWS for feedback

Materials required:

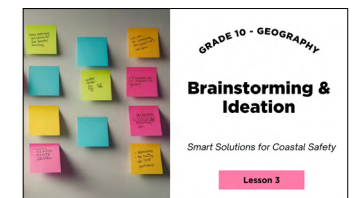
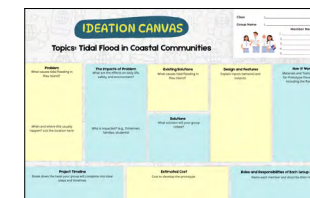
- Laptop/smartphone



SCAN TO ACCESS
• Ideation canvas template



SCAN TO ACCESS
• Teaching slides



a. Hook (10 mins)

Students continued working in groups of four or five. The lesson opened with a short video interview of community members in Batam affected by tidal flooding.



Students were then asked to consider: *“What challenges were the members of the community facing?”* and *“What were their main concerns?”*

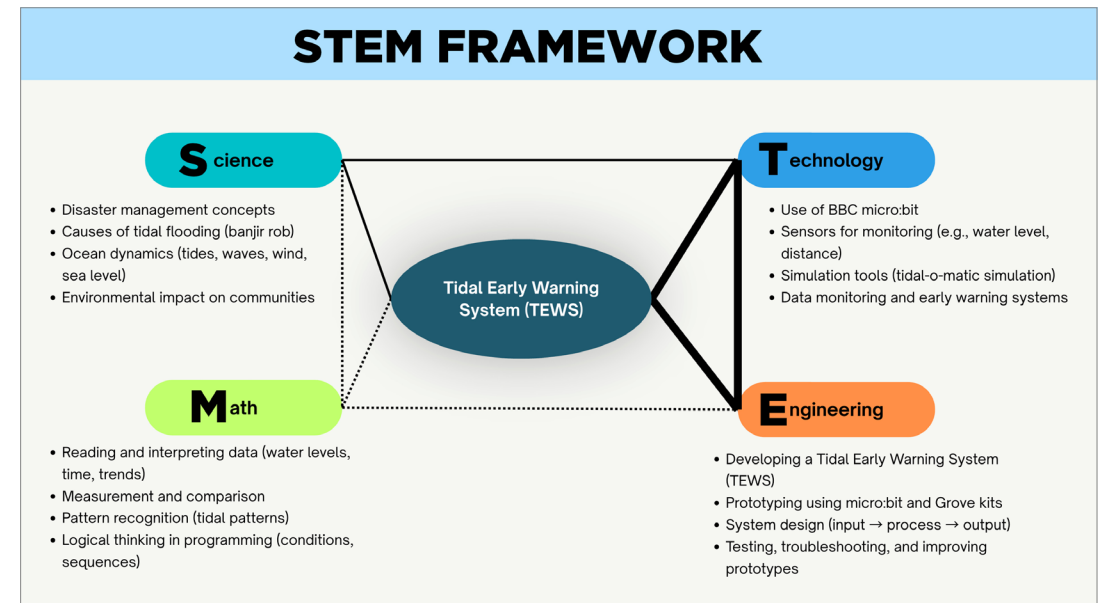
Students then visited the National Agency for Disaster Countermeasure (BNBP) government portal to access real-time data on flooding and natural disasters in Indonesia. The teacher then shared key data on tides from the portal to highlight the urgency and real-world consequences of tidal flooding in Batam.



b. Guided instruction (10 mins)

Next, students were introduced to the Ideation Canvas template, which they completed during the lesson.

To highlight the interdisciplinary nature of real-world problem-solving, the STEM Quartet instructional framework was briefly shared as a guide for ideation.



c. Group discussion and presentations (70 mins)

Students used the Ideation Canvas to brainstorm and select among potential early tidal warning solutions. They were tasked to:

- Identify the problem
- Propose a solution
- Design their version of a TEWS
- Detail the materials, and tools and estimate the cost required for prototype development
- Outline the project timeline
- Delegate roles and responsibilities for each member

Leveraging their prior tinkering experience in lesson 2, students surfaced ideas for discussion and evaluated practical logistics for a chosen solution. They presented their Ideation Canvas to the class, receiving feedback from their peers and teacher for design refinement.

d. Reflection and conclusion (10 mins)

The teacher concluded the lesson by summarising feedback for each group with a reminder to prepare the necessary tools and/or materials for prototyping in the next lesson.

Pedagogical considerations

- Strategic use of open-ended questions during the hook activity can prompt students to reflect more critically on the limitations of existing disaster management measures in their community.
- Foster accountability and equitable participation by assigning specific group roles (e.g., leader, coder, presenter, purchaser, and note-taker) and validating diverse skills sets, perspectives and contributions.

Lesson 4 Prototype development

Specific instructional objectives

After this lesson, students should be able to:

- ✓ Code, assemble, and test a functional TEWS prototype

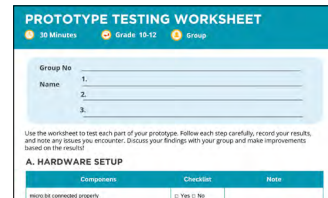
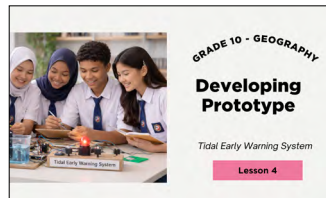
Materials required:



SCAN TO ACCESS
• Teaching slides



SCAN TO ACCESS
• Testing checklist worksheet



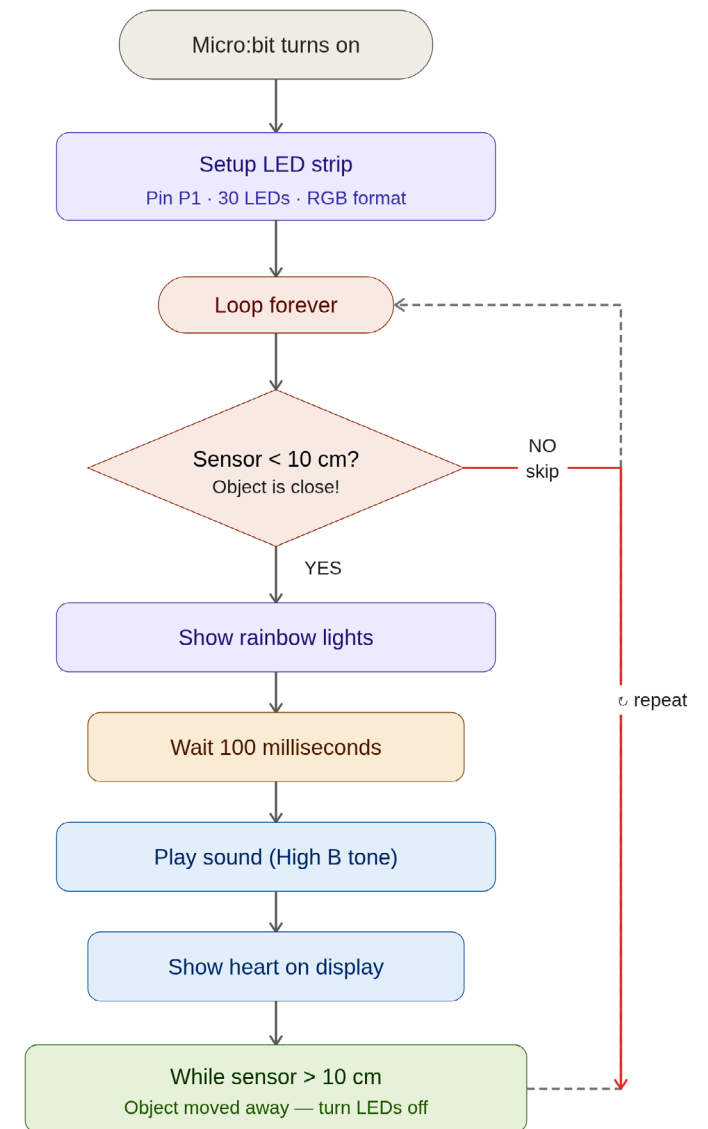
- Laptop for coding
- Final Ideation Canvas

a. Warming up (10 mins)

The teacher began the lesson by reviewing previous key learning points and conducting a quick readiness check, allowing them to identify groups that require support early in the prototyping process.

b. Group prototyping, discussion and presentation (70 mins)

Students constructed their coding scripts using MakeCode and assembled the hardware elements required for their tide-detection prototype by referring to a standardised protocol provided by their teacher.



Standardised protocol to guide the coding process

```

on start
  set strip to NeoPixel at pin P1 with 30 leds as RGB (GRB format)

forever
  if (V2)Ultrasonic Sensor (in cm) at P0 < 10 then
    strip show rainbow from 1 to 360
    pause (ms) 100
    play tone High B for 1 beat until done
    show icon ☺
  while Ultrasonic Sensor (in cm) at P0 > 10
    do
      strip show color black
      show icon ☹

```

Protocol adaptation example employing a dual-alert system: a cross paired with an audio tone warning of potential flooding and a smiley face to denote no tidal flooding risk

Next, students designed and constructed protective outer casings for their prototypes using cardboard or the recycled materials provided to simulate the final aesthetic of their TEWS. To evaluate their TEWS, each prototype was placed inside a clear enclosure which contained a physical model of their community landscape. These models, while not crafted to scale, enabled students to visualise their local geography, test device functionality, and strategically determine the ideal location for their TEWS to be positioned.

As part of the evaluation process, students conducted functional verification tests. For example, they checked on sensor responsiveness and ensured that the sensor output was accurately displayed on the LED interface.



SCAN TO ACCESS
The prototype checklist



c. Reflection and conclusion (10 mins)

The teacher concluded the lesson with a 1–2 minute reflection from each group. Students reflected on:

- What worked
- What challenges they faced
- What they planned to improve on or finish by the next lesson

The teacher then provided feedback, highlighting students' notable progress, and gave students a preview of the activities in the next lesson. Students were assigned to complete their coding and prototype testing as homework.



Students discussing and constructing their models

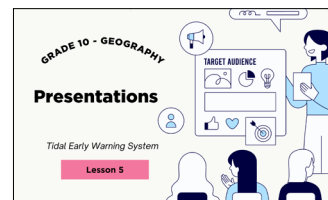
Lesson 5 Project showcase and presentation

Specific instructional objectives

After this lesson, students should be able to:

- ✓ Demonstrate understanding of the key concepts and processes of their prototype
- ✓ Communicate the rationale underlying their ideas clearly and confidently through a structured presentation

Materials required:



SCAN TO ACCESS

- Teaching slides



- Laptop
- Student presentation slides
- Projector and screen

- Completed TEWS prototype (hardware and code) and physical model of the community

a. Warming up (10 mins)

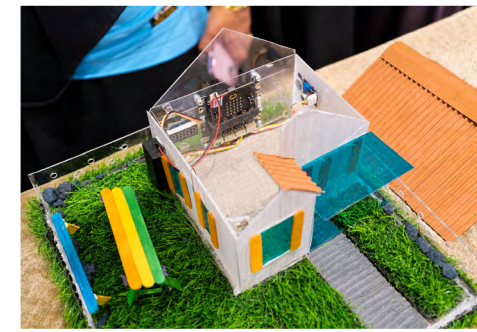
The teacher first welcomed the students and detailed the lesson flow and assessment expectations.

b. Presentations and assessments (70 mins)

Each group was assigned seven minutes to pitch their TEWS and share:

- The problem addressed (tidal flooding)
- The design and function of their TEWS
- Key technical aspects: coding, sensors, packaging
- Challenges encountered and how they overcame them
- Estimated cost, scalability, and potential improvements
- A live demonstration of the prototype

Each group had to also attend to a five-minute Q&A session from their peers and the teacher.



Examples of student prototypes



c. Reflection and conclusion (10 mins)

Following their presentations, students further reflected on their learning through a short class discussion on the skills and insights gained, and their prototyping journey. In the reflection session, they responded to the following questions:

- What did you learn from other groups' projects and presentations?
- What did you learn from the entire five-lesson module?
- What skills did you develop through this project?

Lastly, the teacher encouraged students to explore broader applications of micro:bit technology in disaster mitigation. To sustain interest, students were invited to borrow the micro:bits and Grove Inventor kits for independent, student-directed tinkering and collaborative problem-solving.

STUDENTS' PROJECTS ASSESSMENT RUBRICS

A. PROJECT (TEWS PROTOTYPE)

Criteria	4 (Excellent)	3 (Good)	2 (Fair)	1 (Needs Improvement)
Functionality	System works perfectly; all features function as intended	Works with minor issues	Partially works; several issues	Does not function
Technical Understanding	Clear understanding of coding, sensors, and system logic	Good understanding with minor gaps	Basic understanding	Limited understanding
Design & Engineering	Well-built, neat, and organized prototype	Mostly neat and functional	Some structural issues	Poorly constructed
Innovation & Creativity	Unique features and creative design	Some creativity shown	Limited creativity	No innovation
Problem-Solving Process	Independently solved problems effectively	Solved problems with some guidance	Needed significant support	Unable to solve problems

B. PRESENTATIONS & TEAMWORK

Criteria	4 (Excellent)	3 (Good)	2 (Fair)	1 (Needs Improvement)
Clarity of Explanation	Very clear, logical, easy to understand	Mostly clear	Some parts unclear	Difficult to understand
Demonstration	Prototype demonstrated successfully	Minor issues in demo	Demo partially works	No proper demo
Communication Skills	Confident, clear voice, good engagement	Generally clear	Less confident	Unclear delivery
Team Participation	All members actively involved	Most members involved	Few members involved	One person dominates



SCAN TO ACCESS
The marking rubric

Student voice

“To me, this project wasn’t just about the technical side of building a tool, it was also about empathy. We learned to understand disaster risk within coastal communities and tried to come up with solutions to make their lives safer. It made me realise that the knowledge we gain can be directly applied to help others.”

Cici



“I learned so much from this project, especially about teamwork and creative problem-solving. We failed a few times while designing the tool, but we kept evaluating and improving it. When it finally worked, the satisfaction was incredible!”

Gofur



iii. Challenges and solutions in lesson implementation

Challenge	Possible solution
1. Varying levels of coding knowledge and proficiency caused setbacks during prototype development.	Offer short, focused sessions on key coding and logic concepts to align student skill levels.
2. The lack of personal laptops restricted coding to limited computer lab hours and constrained the time for independent experimentation and iteration.	Extend computer lab availability to breaks and free periods to maximise student use.
3. Collaborative work can create workload imbalances, with a few students dominating while others remain passive.	Pair students with complementary skill levels to foster peer learning and balanced participation.



Teacher's reflections

As a Geography teacher, entering STEM education felt unfamiliar, but I quickly realised how a STEM approach can create meaningful real-world learning experiences.

While coding was challenging, it fostered persistence and innovation, and encouraged students to support and learn from each other during the troubleshooting process.

What surprised me was the energy in the classroom. Students moved from passive learners to curious problem-solvers and were eager to test their prototypes. Stepping out of my comfort zone not only benefitted my students but also reignited my own passion for teaching. STEM is more than combining disciplinary knowledge, it is about preparing students and educators to think critically, and solve the problems of tomorrow.

Mr Deddy Karokaro, Teacher, Sekolah Menengah Atas Negeri (SMAN) 6 Batam



Author's reflections

Through the STEM Capacity Building programme, we have witnessed a profound shift in the classroom, empowering educators to design and implement integrated inquiry-based STEM curricula. Across disciplines, educators are now approaching transforming complex concepts into real-world experiences in creative ways, making collaborative student-centred learning the new standard.

Ms Retna Widiyasrini, Assistant Manager, Program Strategy and Innovation, PJI

Closing Message

Thank you for making it to the end of the publication, *STEM Education in Culture and Context*. We hope you have found it useful, relatable, and actionable. Be sure to check out both parts 1 and 2 of the title for a holistic perspective on STEM Education in Asia.

Readers familiar with our *Making HEADway* handbook series may recognise an earlier edition of this work, *Teaching STEM in Southeast Asia*, developed during the COVID-19 crisis to support efforts in mitigating learning loss. In this revised volume, we have expanded the scope of the series to present a broader range of innovative and practical approaches to STEM education in Asian classrooms.

This publication is also the second in the series to adopt a comprehensive compendium format, following *Becoming Leaders in Sustainability Education*. This reflects our renewed commitment to developing the series as a relevant and robust resource for educators across the region.



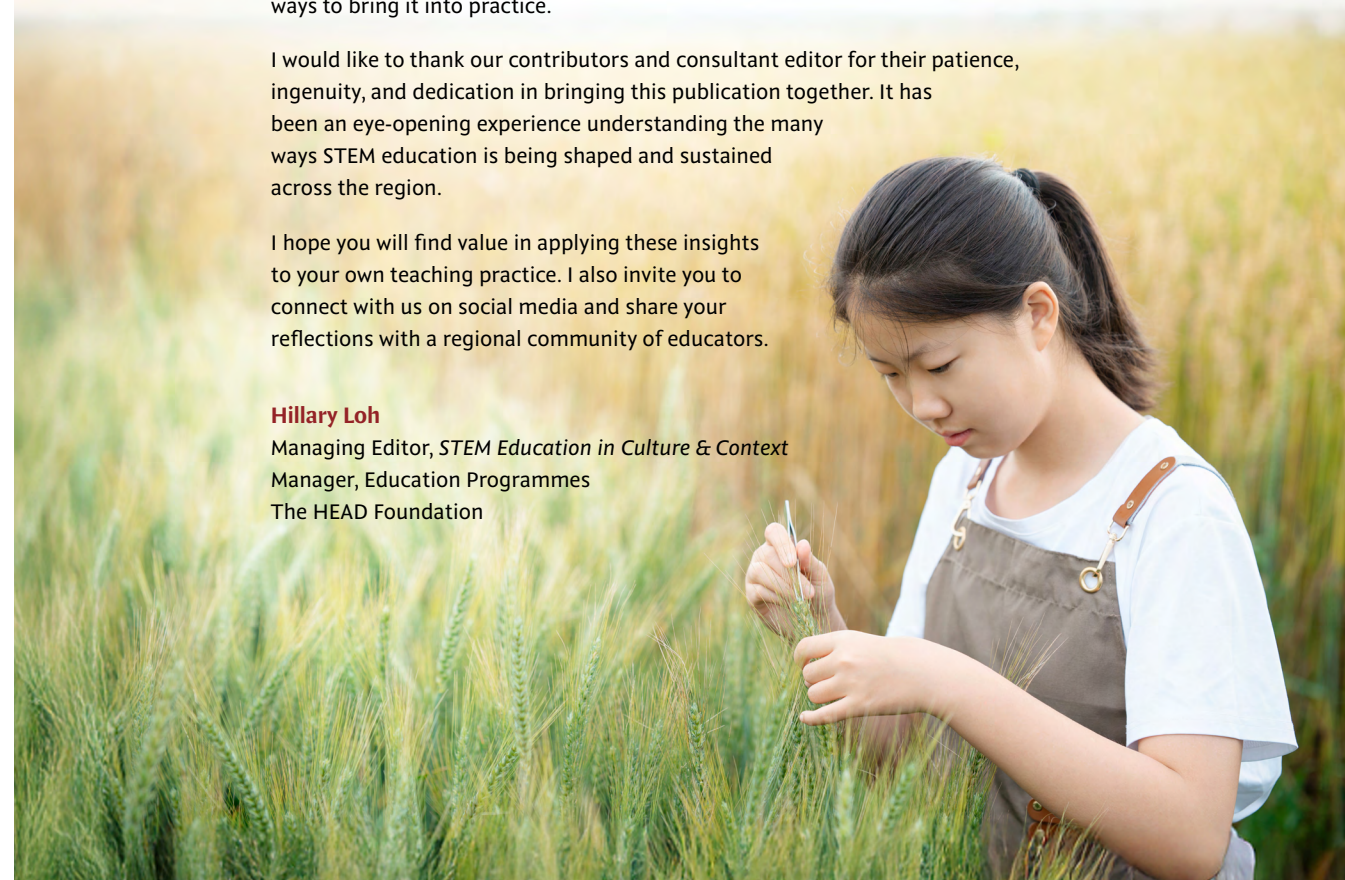
The diversity of lessons presented across subjects highlights that there is no single way to introduce integrated STEM in the classroom. Rather, educators can consider multiple entry points, adapting approaches to suit their context and student readiness. Often, the greater challenge lies not in the complexity of tools or content, but in finding synergy and alignment with fellow educators and making space for iteration and reflection. Teachers can be creative and collaborative in structuring cross-disciplinary lessons, while using simple yet effective pedagogies that enhance learning experiences. We hope this book affirms the formative impact of STEM education on student development, while offering accessible and innovative ways to bring it into practice.

I would like to thank our contributors and consultant editor for their patience, ingenuity, and dedication in bringing this publication together. It has been an eye-opening experience understanding the many ways STEM education is being shaped and sustained across the region.

I hope you will find value in applying these insights to your own teaching practice. I also invite you to connect with us on social media and share your reflections with a regional community of educators.

Hillary Loh

Managing Editor, *STEM Education in Culture & Context*
Manager, Education Programmes
The HEAD Foundation



About

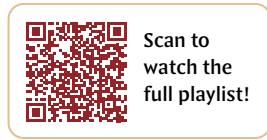
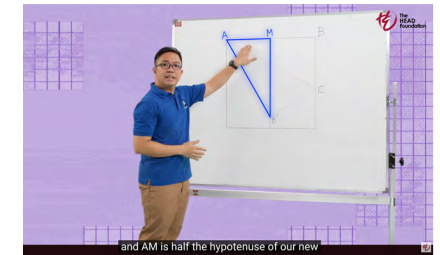
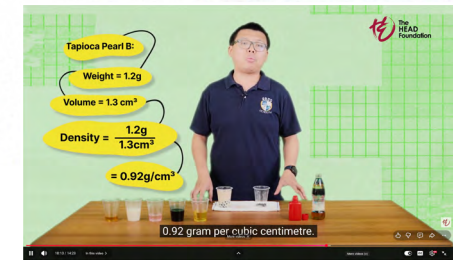
Making HEADway

Making HEADway was conceived, designed, and launched by The HEAD Foundation in 2020. This expanding suite of teacher professional development offerings includes practitioner-focused handbooks for educators, instructional YouTube videos for live lesson demonstrations, webinars, and more. This open access ecosystem focuses on building up teacher capacity and communities of practice among Southeast Asian educators.



Making HEADway CLASSROOM

The latest edition to the ecosystem, Making HEADway Classroom videos feature live lesson demonstrations from exemplary educators in Asia. Pick up detailed lesson ideas, and watch how educators move through lessons in real time to deliver them in a practical and engaging way.



Also in this series

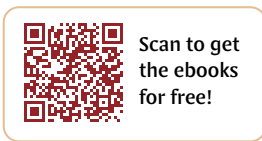
No. 6 | Becoming Leaders in Sustainability Education

This book is a comprehensive resource for educators of diverse subjects to implement Education for Sustainable Development lessons and curricula, based on lived experiences and real-world examples unique to Asia.

Find curriculum and lesson plans across a variety of levels, in the subjects of:

- Geography
- Nutrition and Agriculture
- Coding
- Social Studies
- STEM and Engineering

The 21st-century presents unique and unprecedented opportunities and challenges for humanity and the planet. How do we ensure sustainable development efforts are sustained in the long run and that we equip our future generations with the knowledge and skills for sustainable living?



About

meriSTEM@NIE

Positioned at the intersection of theory, pedagogical practice, and empirical research, the Multi-centric Education, Research and Industry STEM Centre at the National Institute of Education (meriSTEM@NIE) in Singapore drives innovation within the evolving local and global educational landscape. Led by a core mission to enhance the quality of cross-disciplinary STEM literacy and competencies, the centre serves as a research-driven hub that connects academic institutions with industry stakeholders.



Through robust collaborative networks comprising STEM specialists, researchers, academic researchers, educators, and industry leaders, meriSTEM@NIE provides the foundational framework for systemic integration and dissemination of STEM education. This is achieved through teacher- and student-capacity building initiatives, targeted undergraduate and graduate-level courses, and access to pedagogical materials such as peer-reviewed research and toolkits for practitioners and learners alike.

The centre advocates for a unified initiative for the pervasive integration of STEM education, while serving as a strategic regional anchor within Singapore's educational ecosystem.



Visit the centre's online platform to explore more on the research, resources, and partnership opportunities



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The HEAD Foundation is a charitable organisation set up in 2013 in Singapore to contribute to sustainable development in Asia.

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