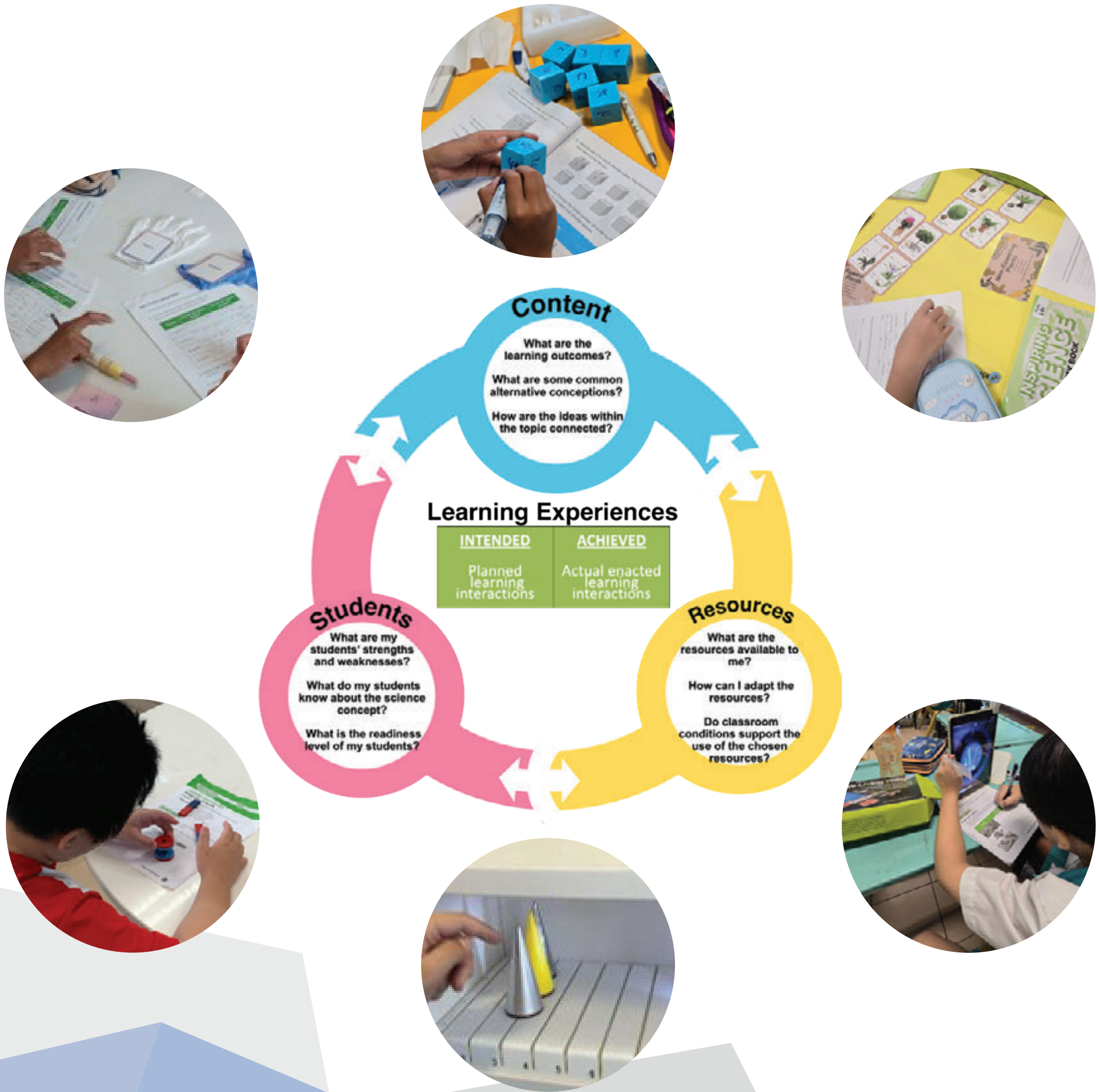
CURRICULAR RESOURCE INTEGRATION AND INNOVATION FOR SINGAPORE PRIMARY SCIENCE

TEACHERS AS PEDAGOGICAL DESIGNERS FOR IMPLEMENTATION INTEGRITY



Ministry of Education
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Curricular Resource Integration and Innovation for Singapore Primary Science: Teachers as Pedagogical Designers for Implementation Integrity

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This monograph describes the key features of the 2023 Primary Science Syllabus in Singapore and how classroom learning experiences have been organised through the use of integrated curriculum resources. Based on observations of Primary 3 and 4 science classrooms and interviews of teachers and students, we propose a thinking frame, the Content-Student-Resource [CSR] Cycle, for teacher planning and reflection. This thinking frame helps to understand how local science teachers have customised their teaching of content through the use of curriculum resources. The CSR Cycle enables teachers to plan and reflect on various pedagogical considerations with sensitivity to their implementation contexts. We exemplify the CSR Cycle with selected stories of actual classroom practices.

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Ethical Consideration
The data reported in this study is approved by NTU IRB-2022-1114.

Acknowledgements
We would like to thank the schools, teachers, and students for allowing us into their classrooms. Being in the classrooms to observe how science learning takes place is a privilege that we do not take for granted. Hence, our heartfelt appreciation goes to the Principals, teachers, and students. We would also like to acknowledge the generous and meaningful feedback from all our colleagues who have taken time to read the drafts of this monograph.

CONTENTS

PROLOGUE

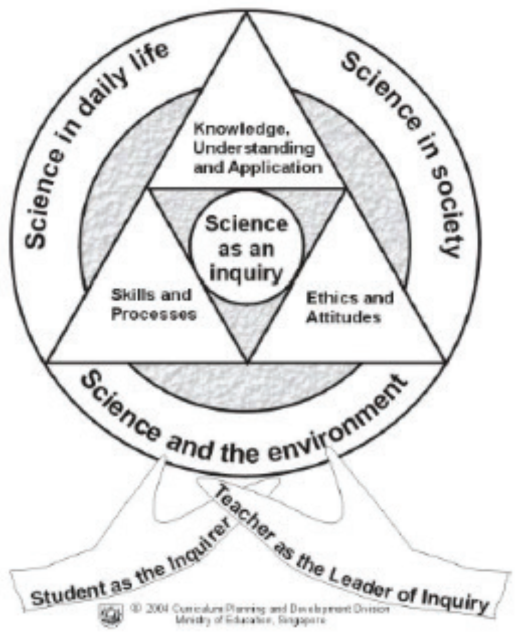
The Primary Science Thematic Syllabus, organised in five themes of Diversity, Cycles, Systems, Interactions and Energy, was first conceptualised and implemented from 2001. These themes support students to appreciate the connection between Physical and Life Sciences in the real world. The syllabus was reviewed and enhanced regularly for implementation in 2008, 2014 and 2023.

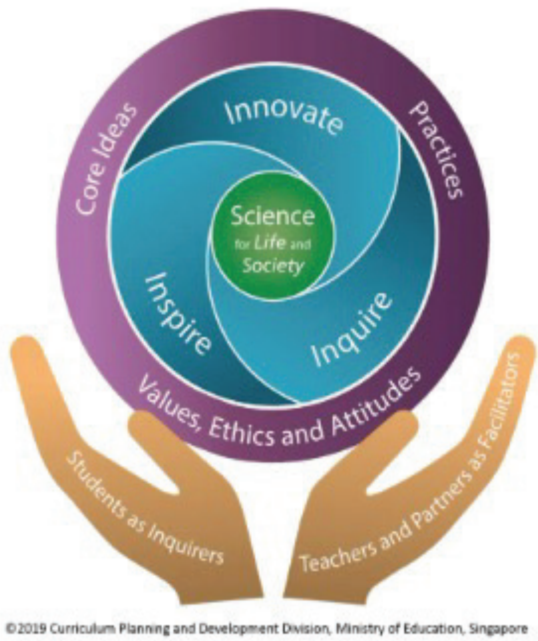
To encourage teaching and learning as inquiry, the Science Curriculum Framework, centred on “Science as an inquiry” was first introduced in 2004. This was further enhanced in 2019 to highlight the importance of “Science for Life and Society”, anchored on the vision of “Inquire, Innovate and Inspire”. The development of core ideas, practices, values, ethics and attitudes are also emphasised with “Students as Inquirers” and “Teachers and Partners as Facilitators”.

“The Science as Inquiry framework gave teachers, teacher educators and curriculum planners a common language to talk about what and how science is learned in the classrooms. This collective purpose has galvanised us to raise the quality of science learning and teaching in Singapore. Two decades on, we know that students here know what the practice of inquiry is. Kudos to our teachers who made it happen in every science classroom.”

Dr Poon Chew Leng
Deputy Director, Sciences Branch
Curriculum Planning and Development Division (2003–2008)

Figure 1 Review of Science Curriculum Framework





For the current 2023 Primary Science Syllabus, an integrated suite of resources was developed for the first time. The suite included the Textbook, Activity Book, Science Pack Activity Resource Kits for Learning (SPARKLE) hands-on kit, Student Learning Space (SLS) supported by the Teaching and Learning Guide. SPARKLE is at the heart of the integrated resources, to encourage hands-on and minds-on learning experiences.

Besides translating the ideas reflected in the Science Curriculum Framework and thematic syllabus into the integrated suite of resources, the meaningful and coherent sequence of learning at the topic and lesson levels are also emphasised through the Conceptual Flow Diagram (CFD) and 3C (Capture, Construct, and Consolidate) Pedagogical Framework respectively. The CFD provides an overview of conceptual progression across a topic. The 3C Pedagogical Framework serves to help teachers structure their lessons for students to engage with specific scientific phenomena, build explanations, and consolidate their learning systematically.

"The 3C pedagogical framework was developed with teachers and for teachers. It draws on both research and the expertise and experiences of practising teachers in Singapore.

Together with the range of resources that the Science Curriculum Specialists have put into the hands of teachers, this has helped us move forward in helping our students stay engaged and curious about science."

Dr Poon Chew Leng

'Tell me and I forget. Teach me and I remember. Involve me and I learn.' – Benjamin Franklin

"This encapsulates the approach that Singapore has taken in the development of the primary science syllabus and suite of teaching and learning resources across the years. Children are naturally inquisitive. The beauty of the primary science syllabus lies in its ability to activate this sense of curiosity in young learners, steering this curiosity into evidence-based sensemaking through play, and laying the foundation for a lifelong competency to be able to practice inquiry in their daily lives.

This effort would not have been possible without the partnership of the National Institute of Education and Science Centre Singapore. May our students experience the joy of learning and see science come alive!"

Mdm Lee Lin Yee
Director, Sciences Branch
Curriculum Planning and Development Division (2020–2023)

Over the years, CPDD, AST and NIE have worked in close partnership, from syllabus conceptualisation, to resource development as well as professional development. With the development of the integrated suite of resources for the first time for the 2023 Primary Science Syllabus, this monograph captures the curricular and resource considerations over syllabus cycles and more importantly, stories of how the syllabus and resources are translated into science teaching and learning across topics. Teachers have shown agency in customising resources considering curricular intent and students' needs, showing professionalism in implementing the curriculum with integrity.

"Primary Science learning should transcend the endless practice of worksheets. It should pique our children's curiosity to learn through doing and exploring. This conviction led us to address a fundamental challenge: How can we enable teachers to deliver an engaging, hands-on Science curriculum despite constraints of time, facilities and resources in the primary school setting?

This project is a remarkable collaboration among domain experts in curriculum design, pedagogy, educational research and science edutainment. I am glad this multi-year initiative has culminated in an invaluable resource for our teachers in their important work of kindling a lasting passion for discovery among our young learners.

Indeed, the success of this endeavour demonstrates what we can achieve with a united vision for Science education."

Sin Kim Ho
Divisional Director
Curriculum Planning and Development Division (2018–2022)

"The partnership between CPDD Curriculum Specialist, AST Master Teachers, NIE Lecturers and Schools has deepened the pedagogical content knowledge of teachers for quality student learning. This strong partnership and teacher commitment have helped to build a culture of teacher-led professionalism and pride in the Primary Science Fraternity.

Let us continue to champion professional collaboration and learning. When we unite in partnership and collaboration, we create a symphony of knowledge, a harmony of growth and a legacy of learning that is beyond the classroom walls. It is our desire to cultivate students' love and passion for science so that they are inspired to learn and use Science meaningfully in their everyday lives and in the society."

Mrs Chua Yen Ching
Divisional Director
Curriculum Planning and Development Division (2011–2013)

SECTION A

SCIENCE CURRICULAR AND PEDAGOGICAL FRAMEWORKS

How is the Syllabus organised?

5 Themes

Diversity | Cycles | Systems | Interactions | Energy

9 Topics (in P3 and P4)

- Diversity of Living Things
- Diversity of Materials
- Cycles of Plants and Animals (Life Cycle)
- Interaction of Forces (Magnet)
- Plant System (Plant Parts and Functions)
- Human System (Digestive System)
- Cycles in Matter and Water (Matter)
- Energy Forms and Uses (Light)
- Energy Forms and Uses (Heat)

How is a Topic organised?

Conceptual Flow Diagram

Essential Takeaways
Key Inquiry Questions

Key Idea → Linking question → Key Idea → Linking question → Key Idea → Linking question → Key Idea

Let's Create

How is a Lesson organised?

3C Pedagogical Framework

Capture → Construct → Consolidate

A1. How is the 2023 Primary Science Syllabus organised?

The Primary Science Syllabus aims to provide students with experiences/opportunities to:

- build on their interest and stimulate their curiosity about themselves and their environment
- acquire basic scientific concepts to help them understand themselves and the world around them
- develop skills, dispositions, and attitudes for scientific inquiry
- apply scientific concepts and skills in making responsible decisions
- appreciate how Science influences people and the environment

Table 1 Overview of Themes, Essential Takeaways, and Key Inquiry Questions

Themes	Diversity	Cycles	Systems	Interactions	Energy
Essential Takeaways	There is a great variety of living and non-living things around us. We classify living and non-living things based on their similarities and differences. Maintaining the diversity of living and non-living things is important for survival.	There are repeated patterns of change around us. Understanding cycles helps us to make predictions about events and processes around us.	A system is made of different parts. Each part has its own unique function. Different parts of a system influence and work together to perform function(s).	There are interactions among us, living and non-living things in the environment. Interactions within the environment can have positive or negative impacts. Conservation is important to ensure continuity of life and availability of resources.	Energy is required for things to work. There are various forms of energy and they can be converted from one form to another. Some sources of energy can be depleted and we play an important role in energy conservation.
Key Inquiry Questions	What can we observe around us? How can we classify the great variety of living and non-living things? Why is it important to maintain diversity?	What makes a cycle? How does a cycle help us predict events and processes? Why are cycles important to life?	What is a system? How do different parts and systems work together to perform function(s)? Why is it important to understand how parts/ systems work together?	What are the types of interactions around us? How do interactions affect the environment and us? Why is it important for us to conserve the environment?	What are the different forms of energy around us? How is energy used in everyday life? Why is it important to conserve energy?

With the aims in mind, the syllabus is organised into five **themes**: **Diversity, Cycles, Systems, Energy, and Interactions**

- These themes encompass a core body of concepts in both the life and physical sciences. This body of concepts has been chosen because it provides a broad-based understanding of the environment, and it will help build a foundation upon which students can rely on for further study.
- To help teachers and students appreciate and understand the themes, essential takeaways and key inquiry questions are included for each theme. These essential takeaways and questions can guide teachers and engage students in uncovering the important ideas at the heart of each theme. They can also use these questions to raise more specific questions for the respective topics under each theme.

Although the content of the syllabus is organised into five themes, the topics under each theme are not to be viewed as compartmentalised blocks of knowledge. In general, there are no clear boundaries between these themes. There may be topics common to different themes. Hence, a conscious effort is needed to demonstrate the relationship between themes whenever possible.

Table 2 Overview of Themes and Topics across Levels

Levels	P3	P4	P5	P6
Themes	Diversity Cycles Systems Interactions Energy			
Topics	Diversity of living and non-living things (General characteristics and classification) Diversity of materials Cycles in plants and animals (Life cycles) Interaction of forces (Magnets)	Plant system (Plant parts and functions) Human system (Digestive system) Cycles in matter and water (Matter) Energy forms and uses (Light) Energy forms and uses (Heat)	Cycles in plants and animals (Reproduction) Cycles in matter and water (Water) Plant system (Respiratory and circulatory systems) Human system (Respiratory and circulatory systems) Electrical system	Energy forms and uses (Photosynthesis) Energy Conversion Interaction of forces (Frictional force, gravitational force, elastic spring force) Interactions within the environment

A2. How is a topic organised?

For each topic in the syllabus, the sequence of learning of concepts is presented in a Conceptual Flow Diagram (CFD). The diagram supports teachers in designing students' learning experiences across a topic. Some of the features in a CFD are shown in Figure 2, in the topic of Diversity of Living and Non-living things.

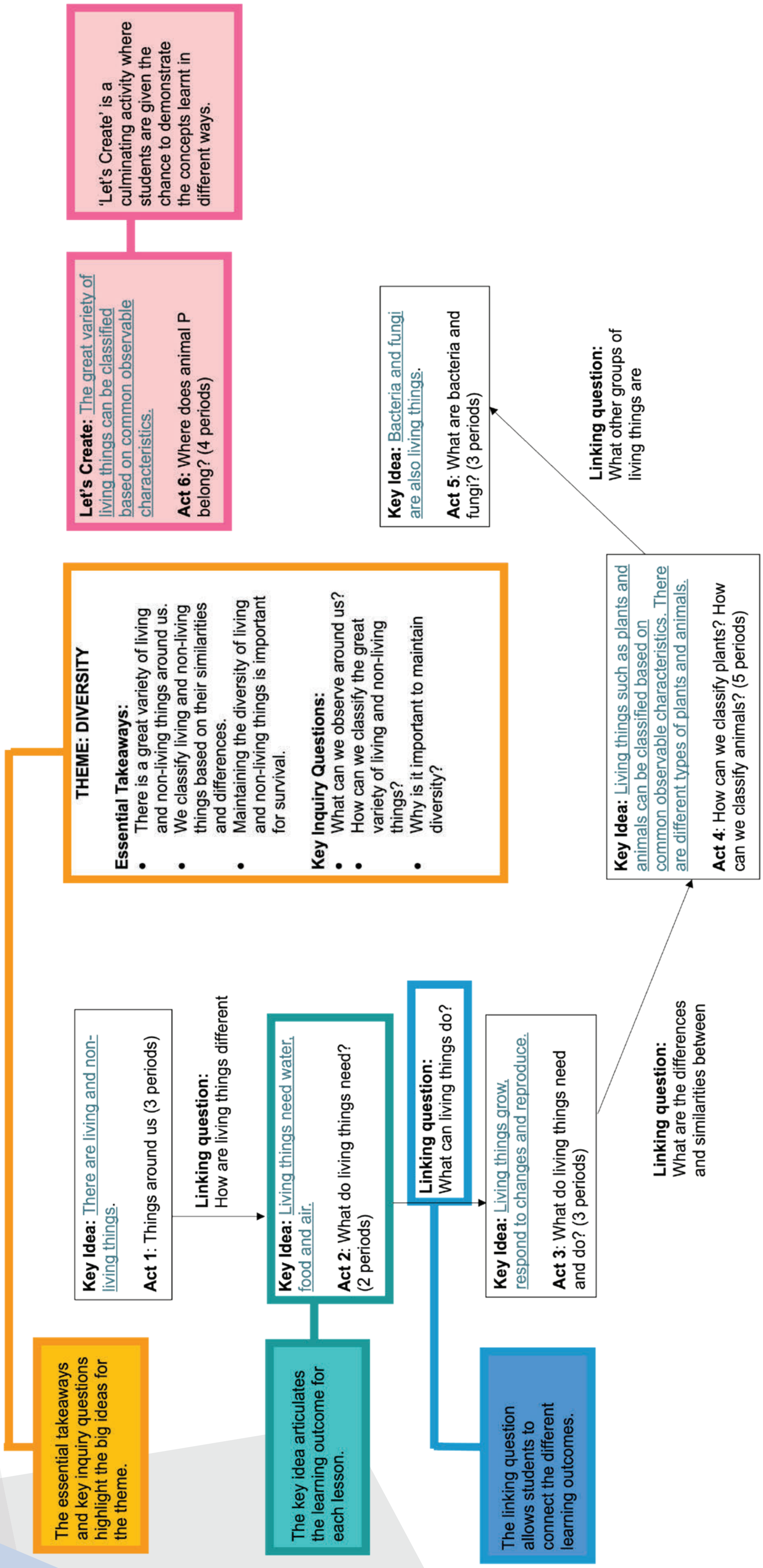


Figure 2 Conceptual Flow Diagram for a Topic: Diversity of Living and Non-living Things

A3. How is a lesson organised?

The 3C Pedagogical Framework[1] guides the sequencing of learning within a key idea, where a teacher **captures** students' attention, facilitates students' **construction** of concepts and skills, and **consolidates** the learning of the students. Table 3 shows some guiding questions that can help teachers in the planning.

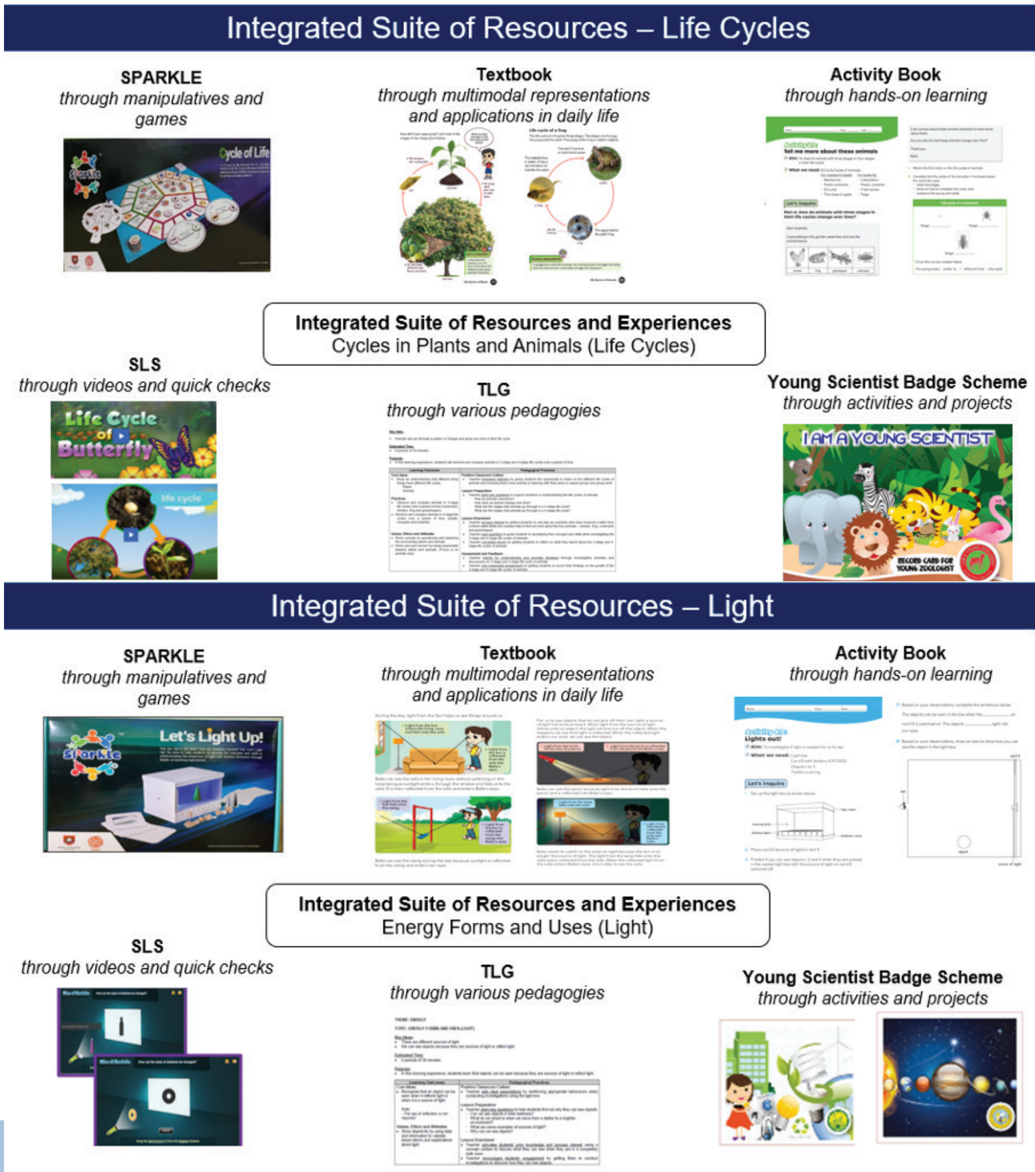
Table 3 Overview of 3C and Guiding Questions

Stage		What	How
Capture ideas and interest	Teacher generates interest for the lesson and activates students' prior knowledge.	• What are some of the students' prior knowledge? • What is the next concept that students are learning?	• How can teachers elicit students' prior knowledge? • How can teachers generate students' interest for learning the next concept?
Construct understanding	Teacher develops concepts, skills and attitudes through hands-on and minds-on learning experiences.	• What concepts and skills do students have to learn? • Are there content gaps to bridge?	• How can teachers teach and help students construct the concepts? • How can teachers bridge the content gaps?
Consolidate learning	Teacher summarises learning and encourages application in new contexts.	• What is the key idea in this lesson? • What are other ideas learned that are connected to this idea?	• How can teachers help students apply what they have learnt? • How can students summarise their learning?

1 Poon, C. L., Lee, Y. J., Tan, A. L., & Lim, S. L. (2010). *Knowing Inquiry as Practice and Theory: Developing a Pedagogical Framework with Elementary School Teachers*.

SECTION B
AN INTEGRATED SUITE OF RESOURCES

In Primary Science, an integrated suite of resources comprising the Textbook (TB), Activity Book (AB), Science Pack Activity Resource Kits for Learning (SPARKLE), Student Learning Space (SLS)[2], Young Scientist Badge Scheme (YSBS) and Teaching and Learning Guide (TLG) is developed. Each resource plays unique yet complementary functions in supporting science teaching and learning across different themes and topics.



2 SLS is Ministry of Education's core platform for teaching and learning and is one of MOE's key initiatives to transform the learning experiences of Singaporean students.

B1. What are the design considerations?

The integrated suite of resources supports teaching and learning of science, while developing students' 21st century competencies such as Critical, Adaptive and Inventive Thinking (CAIT) and Communication, Collaboration and Information Skills (CCI). The following design considerations guide the development of these resources:

Alignment with primary science curriculum

These resources are intentionally designed to provide clarity on curriculum intention and to progressively develop students' understanding of core ideas, practices, values, ethics, and attitudes through various features.

Engaging students in hands-on and minds-on inquiry-based experiences

The resources are designed to encourage students to:

- Be Inspired by science: Incorporation of real-world applications helps students appreciate the relevance of science in their everyday lives.
- Inquire like scientists: Inquiry-based learning experiences encourage students to engage in the practices of science. Given students' concrete operational stage of development, hands-on inquiry learning experiences are complemented by meaningful online learning to facilitate students in making connections.
- Innovate using science: Students apply concepts and practices to generate solutions such as creating toys and solving problems posed in the Let's Create learning experiences.

Accessible and easy to use

Resources are designed to cater to diverse students' needs. In the Textbook and Activity Book, there is coherence and consistency in the structure across topics and levels to guide learning experiences while reducing cognitive load. In SPARKLE, design features (e.g., colour, size, grip) are included to ensure safety and ease of manipulation, as well as support students with special needs (e.g., colour blindness). Teachers are also provided with flexibility and agency to customise resources according to their students' needs.

B2. What makes up the integrated suite of resources?

Each resource embodies the design considerations above, and serves unique yet complementary functions in the teaching and learning of science.

Textbook

The Textbook is a source of age-appropriate knowledge. Features in the Textbook (e.g., Science Around Us, Let's Think and Do, I'm Inspired, comics and characters) develop core ideas, practices, values, ethics and attitudes as well as encourage scientific discourse. The Textbook also acts as an organising frame and link to learning experiences in other resources (e.g., AB and SLS) through the "Let's Inquire" feature.

Activity Book and SPARKLE

The Activity Book and SPARKLE are tightly coupled to encourage hands-on and minds-on investigations. Students collaborate to conduct investigations, analyse and interpret data, as well as construct explanations to deepen conceptual understanding and develop science practices. For example, in Diversity of Materials, students conduct investigations suggested in the Activity Book using SPARKLE objects made of different materials but identical sizes to learn about the properties of materials and the nature of a fair investigation.

Student Learning Space (SLS)

The resources in SLS (e.g., videos, animations and interactives) tap on the affordances of technology to complement hands-on learning experiences. Abstract concepts can be represented through rich visuals to develop concepts. For example, a video showing temperature changes through colour variation helps students visualise heat flow and distinguish between heat and temperature. SLS can also support assessment for learning where teachers can tap on the “quick check questions” to assess students’ understanding and provide feedback.

Young Scientist Badge Scheme (YSBS)

The YSBS[3] extends science learning beyond the curriculum and classroom, encouraging students to be inspired by science in their daily lives. For example, students apply heat concepts to creatively build a solar oven, or explore the Earth’s rotation to understand the phenomenon of day and night. These tasks encourage students to take ownership of learning driven by personal curiosity and interest.

Teaching and Learning Guide (TLG)

The TLG[4] offers teachers guidance on concept sequencing and resource integration, leveraging the unique functions of each resource. Additionally, the TLG offers suggestions for alternative learning experiences to address diverse learning needs. Although the TLG provides a guide to teachers on teaching and learning of science, it is not meant to be prescriptive as teachers have the agency to customise the resources according to their schools’ contexts, and students’ needs.

3 Young Scientist Badge Scheme is designed to inspire interest in and encourage the exploration of Science, Technology, Engineering and Mathematics (STEM) disciplines among primary school students.
4 Teaching and Learning Guide is designed to support Singapore teachers in using the integrated suite of resources.

SECTION C

STORIES FROM SCIENCE CLASSROOMS: TEACHING AND LEARNING EXPERIENCES

1 Diversity of Living and Non-Living Things
Seeing the “invisible”

#Exploration #Curiosity

2 Diversity of Materials
Check your ‘special’ book

#Communicating ideas #Handling infomation

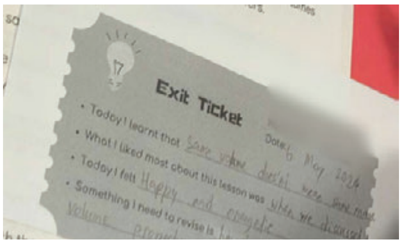
3 Cycles in Plants and Animals (Life Cycles)
We can wiggle like a worm

#Role play #Embodied Experiences

4 Interaction of Forces (Magnets)
Attract or Repel?

Embodied Experiences # Multi-modal Representations

5 Cycles in Matter and Water (Matter)
Same volume, same mass? Think again!

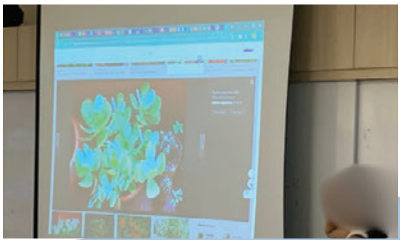


Making sense of data and developing explanations # Investigation

6 Human System (Digestive System)
Grandma says, “Chew your Food”. Is she right?

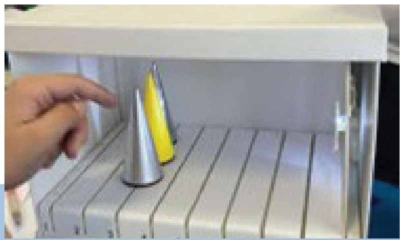
Modelling # Science-Math Connections

7 Plant System (Plant Parts and Functions)
Is Cactus a plant?



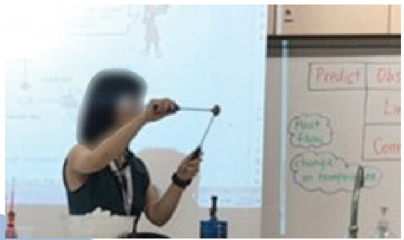
#Making sense of information # Comparing

8 Energy Forms and Uses (Light)
Can Ben see the minion in a dark room?



#Modelling #Representing light rays

9 Energy Forms and Uses (Heat)
Did the ring expand or did the ball contract?



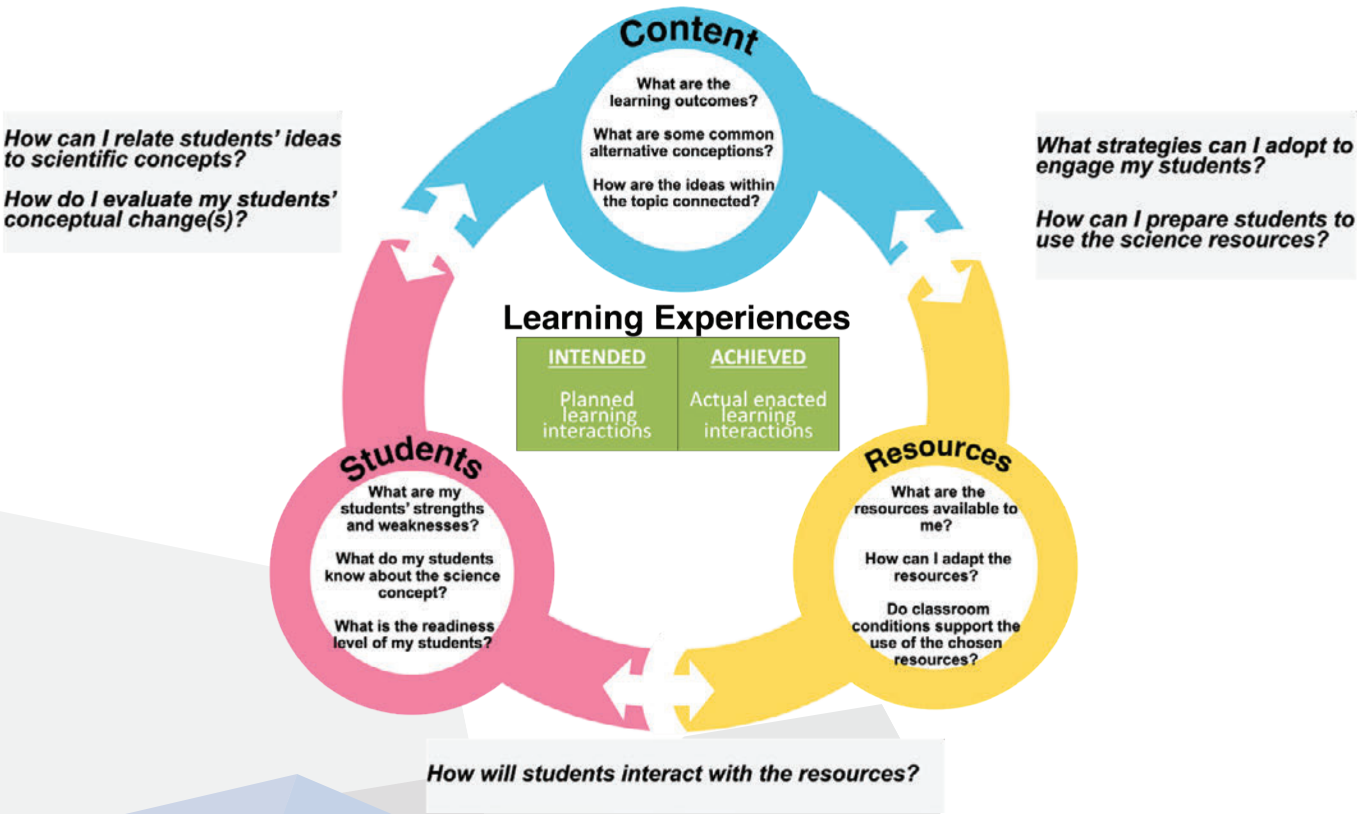
#Demonstration # Observation and discussion

Following the release of the revised Science Curriculum Framework in 2019 and the 2023 Primary Science Syllabus and resources, teachers in Singapore have played key roles in translating their understanding of the framework, syllabus and resources and customising curriculum resources into meaningful learning experiences for their students. Finding out teachers' pedagogical reasoning as they work with the curricular disciplinary ideas and resources within their unique classroom contexts therefore are important to understand how teachers enact the syllabus with implementation integrity.

Based on observations of 50 P3 and P4 science lessons using the integrated suite of resources across nine topics in the P3 and P4 syllabus, we have developed a thinking frame – the Content-Student-Resource (CSR) Cycle – for teacher planning and reflection (see Figure 3). The CSR Cycle is grounded in empirical data, based on teachers' pedagogical considerations and practices. It offers a powerful way to analyse the various roles that resources play in teachers' planning and enactment of science learning experiences. These classroom interactions include those between teachers-resources, teachers-students, students-students, and students-resources.

The CSR Cycle assists teachers in lesson planning and enactment, enabling them to achieve "Students as curious and creative inquirers" as well as "Teachers as designers and orchestrators of learning experiences." In addition, it serves to put ideas from the CFD (considerations of Content) and 3Cs (teaching strategies to be adopted) together in a coherent plan for meaningful science learning.

Figure 3 Content-Student-Resource Cycle for Planning and Reflection



What was its inspiration? City, Elmore, Fiarman and Teitel (2009) made the case that it is essential to consider students and teachers in the presence of content matter for every successful learning task to occur. This tight but dynamic coordination comprised what is known as the instructional core. Hence, anything that enhances the relationships between these elements or within each of the three elements will improve learning. Placing great importance on the interacting roles of teachers, students, and content matter were also expressed in research on curriculum making by a leading geneticist and educator Joseph Schwab (1973). He identified these three elements (and others) as “commonplaces” of curriculum, which is to say that these were all to be regarded as right or true by conventional wisdom.

We propose, however, that the teacher is the chief designer of instruction who considers how their students learn best and the resources needed to develop their understanding of the content. Thus, from this perspective, we replace the role of teachers that is already present in every enactment of instruction within school contexts, with “resources” (e.g., Textbooks, Activity Books, SPARKLE kits, SLS) since these tangible materials are key in facilitating teaching and learning experiences. Similar to the instructional core, within each element, teachers may ask questions about their relevant characteristics or features in order to carry out learning effectively. For example, with respect to content matter, teachers have to make decisions about the selection of appropriate learning outcomes, the sequence of their presentation, and how fast or slow their pacing should be within a lesson or topic. As teachers know too well, every class is very different; what worked very well in one class might not transfer well in another simply because of different classroom environments and many other factors.

This is where other parts of the thinking frame will come in. A thoughtful teacher brings with him/her knowledge of his/her students and their learning needs, and the science resources that are available to adopt or more often, to adapt. Each element is important as much as the interactions or relationships between these three major elements in the thinking frame. We also substituted tasks (i.e. what students are actually doing) in the model by City et al. (2009) with intended/achieved learning interactions or experiences given our focus on teacher’s use of resources during planning and implementation. Hence, by naming the thinking frame as the Content-Student-Resource (CSR) Cycle, science teachers can use it in planning and understanding the implementation of science syllabus and resources. Indeed, developing the CSR Cycle was motivated by questions that teachers raised frequently—What is the content intended for this lesson? What is the profile of my students? What learning experiences do I want to create? What are the curriculum resources available? What teaching strategies should I adopt? How do I make connections between students’ spontaneous ideas and scientific knowledge?

As all these questions are iterative during lesson planning and enactment, there is no fixed starting point. We can thus approach the CSR Cycle from any of its three apices (content, students or resources), and indeed all three elements of this thinking frame should be considered together. The questions in the rectangular grey boxes (see Figure 3) represent some of the critical thinking processes that teachers often ask themselves as they make pedagogical decisions and reflect to connect each part. Finally, we placed the intended and actual learning experiences that students are engaged in right at the centre to help teachers envisage their intended learning interactions or experiences and reflect on their enacted or achieved learning experiences after the completion of teaching.

As resources are not self-acting, Cohen, Raudenbush, and Ball (2003) highlighted the need to probe interactions between teachers and students over specific content to offer finer clues to the role resources play in instruction. Teachers are key in facilitating learning experiences and exploration, by choosing and sequencing resources. They also have to balance the use of teacher-guided and student-centred learning experiences that support students to switch between everyday and scientific concepts to achieve conceptual understanding. Vygotsky's theory suggests that 'good learning' takes place in the Zone of Proximal Development: A place where learners are cognitively stretched, but still receive assistance from others. Hence, educative experiences are those experiences that are both challenging and suitably supported. Research findings have shown that curriculum materials and teachers' knowledge, when used meaningfully during instructional actions bridge what students observe and manipulate with the intended scientific concepts (Leinhardt, Zigmond, & Cooley, 1981).

In the next section, we present nine stories of how P3 and P4 Science teachers customised the integrated suite of resources with different pedagogies to support student experiences and exploration. These stories were curated keeping in mind the developing literacy and numeracy competencies of young children. We were also mindful of what research has reported about science learning in young children—(1) students learn through active participation in science practices (NGSS, 2013), (2) students should engage in reasoning publicly as they develop claims from evidence (Zembal-Saul, 2009), (3) students should build explanations where they actively coordinate theory and evidence (Herrenkohl et al, 1999), (4) students should develop proficiency to apply, explore, and learn science concepts as they participate in science practices such as developing models, analysing data, and constructing explanations, and (5) students should develop and revise science ideas themselves.

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Table 4 An Overview of Stories from P3 and P4 Science Classrooms

	Topics	Pedagogies /Focus	Overview
1	Diversity of Living and Non-Living Things	• Exploration • Curiosity	Seeing the 'invisible' • Using the microscope as a tool for exploration. • Collecting and using empirical evidence in science
2	Diversity of Materials	• Communicating Ideas • Handling Information	Check your 'special' book • Developing language to communicate observations • Handling information in Textbooks
3	Cycles in Plants and Animals (Life Cycles)	• Role play • Embodied Experiences	We can wiggle like a worm • Embodying key characteristics and behaviour of organisms in different stages of life cycle of an insect
4	Interaction of Forces (Magnets)	• Multimodal Representations • Embodied Experiences	Attract or Repel? • Experiencing interactions of magnets through body movement, slide animation, hands-on exploration, and diagram annotation
5	Cycles in Matter and Water (Matter)	• Investigations • Making sense of data and developing explanations	Same volume, same mass: Think again! • Using questions to scaffold sense-making of data to develop explanations
6	Human System (Digestive System)	• Modelling • Science-math Connections	Grandma says, "Chew your Food". Is she right? • Visualising human digestive system • Investigating role of surface area in digesting food
7	Plant System (Plant Parts and Functions)	• Making sense of information • Comparing	Is cactus a plant? • Applying scientific concepts in decision making • Comparing similarities and differences of different plants
8	Energy Forms and Uses (Light)	• Modelling • Representing light rays	Can Ben see the minion in a dark room? • Observations as evidence for claim that light is needed for sight • Representing light rays to communicate science ideas related to light
9	Energy Forms and Uses (Heat)	• Demonstration • Observation and discussion	Did the ring expand or did the ball contract? • Making abstract concept of expansion and contraction more concrete

SECTION C

STORIES FROM SCIENCE CLASSROOMS: TEACHING AND LEARNING EXPERIENCES

Nine stories are represented in this section. The stories describe events in classrooms where scientific concepts are presented and discussed, as well as where scientific practices and values are practised. The stories should be read with the following questions in mind:

- What are the learning outcomes that each teacher was trying to achieve?
- How were the integrated suite of resources adopted or adapted to achieve the learning outcomes?
- What were the pedagogies used by each teacher to enact the lesson?
- What were evidence of learning by students?
- How did content, resources, and students interact to enact the learning experience?

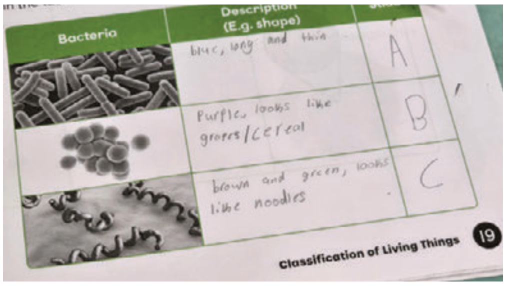
C1. Seeing the 'Invisible'

Bacteria and fungi are microscopic organisms that are not visible to our unaided eyes. As such, compared to larger living things such as cats, lions, or even elephants, students tend to be less familiar with the structures and behaviours of bacteria and fungi (Byrne, 2011). Consequently, students are curious about the world that is 'invisible' to them. Ruiz-Gallardo and Panos (2018) found that primary school students often hold negative or erroneous ideas about microorganisms. For instance, microbes are often associated with diseases and morphically resemble miniature versions of animals with arms and legs (Byrne, 2011). With tools such as microscopes, students are able to see microscopic living things and objects, thereby demystifying the world of microbes. The use of tools to facilitate the work of scientists characterises the empirical nature of scientific inquiry where knowledge is evidence-based. To a very large extent, the advancement of scientific knowledge is dependent on the tools available for examining the world around us.

To help students understand the diversity of living things around them, they can be introduced to organisms that are not immediately visible with their unaided eyes. Allowing young children to explore with hand-lenses or portable microscopes offers excellent opportunities for inquiry and exploration. In the classrooms that we visited, students were instantly excited when they received the microscopes. They were quick to examine their school bags, hair follicles on their arms and whatever objects that caught their attention.

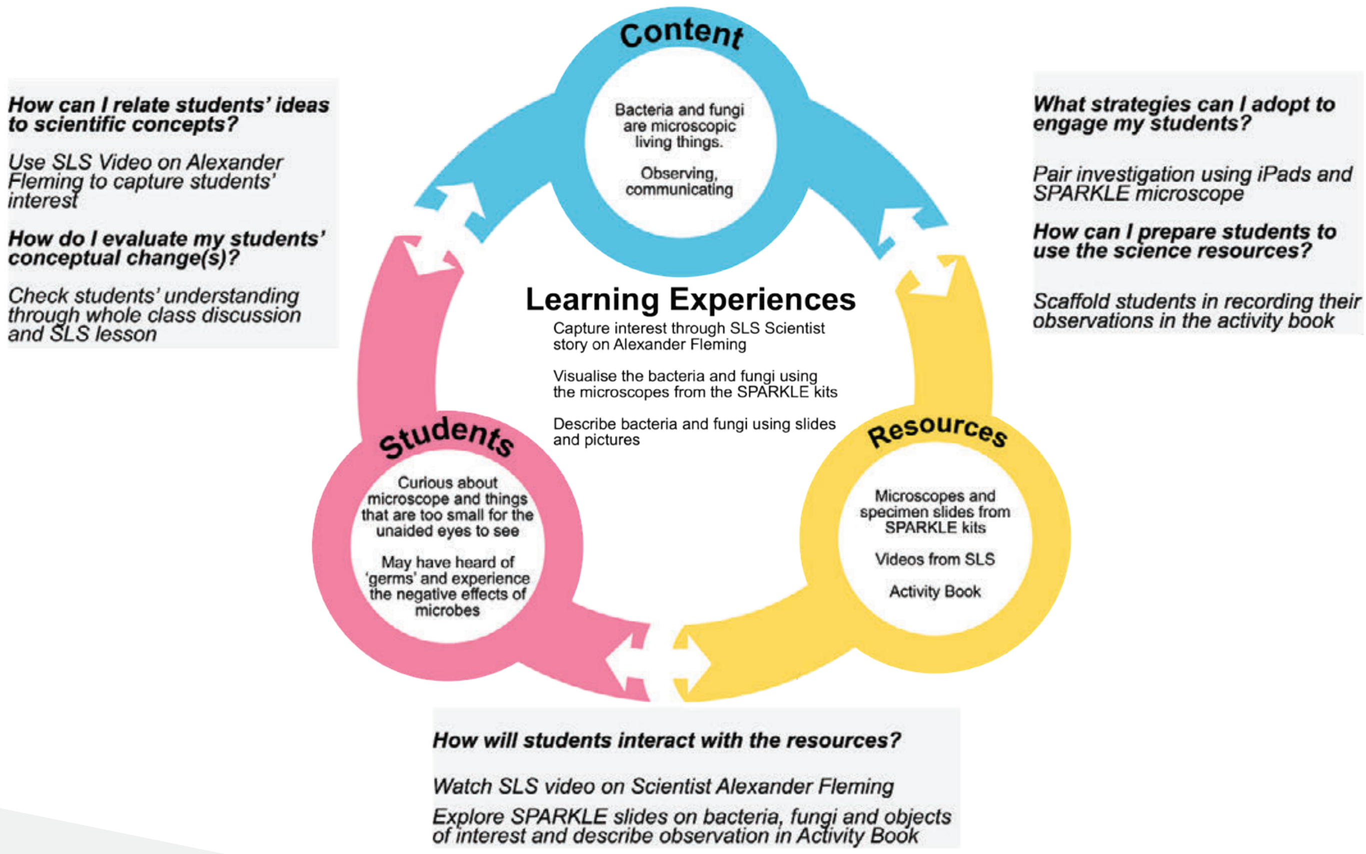
In this chapter, Mr J used the Student Learning Space (SLS) as a medium for students to watch videos and learn ideas pertaining to the discovery of microorganisms. He also used SLS for students to present their ideas and facilitated whole class discussions on exploration with the microscope.

Mr J's Class – Increasing Student Agency in Exploring and Gathering Evidence Curricular Intent		Resource Use
	Capture	
Preparing students for the lesson by stating the theme/topic and resources for the day	Mr J started the lesson by getting two students to distribute the worksheets taken from the Activity Book to every student. He introduced the lesson by stating that they were continuing with the topic of living and non-living things and the diversity of organisms. He told students that they would be working with the microscopes and tablets for the lesson. Group leaders were assigned to collect two tablets per group of four students. Another member of the group was to collect the SPARKLE Kits. The whole SPARKLE kit was given to each group instead of only the required components for the day. Handing out the whole SPARKLE kit provided an opportunity to teach students responsibility to take care of the resources provided for them. Mr J informed the class that he had assigned the lesson on Student Learning Space (SLS), and they would learn in pairs before going through the materials together as a class. Each pair of students was given an iPad to respond, and one member of each pair logged into their SLS account.	
Discussing story of scientist in pairs	Mr J played the SLS video of Alexander Fleming as a scientist who studied causes of diseases. The students watched the video as a class and then discussed in pairs. Mr J played the video again and reminded students to pay attention to answer questions related to the discovery of penicillin.	**Using SLS video to learn about the discovery of penicillin**
Communication of ideas through text	Once the video was stopped, the students started discussing and recording their ideas using "I see, I think, I wonder" in the iPads. Some students were asking their partners how to spell words such as 'diseases'. Mr J used the SLS to pace and monitor the progress of students' learning.  **Keying in observations and questions for SLS Video in iPads**	**Using SLS to pace and check students' progress and support peer critique of ideas**

Mr J’s Class – Increasing Student Agency in Exploring and Gathering Evidence		
Curricular Intent		**Resource Use**
	Once the students had submitted their responses, Mr J showed on the screen all the students’ SLS responses and facilitated a whole class discussion on what different pairs see, think, and wonder.	
	Construct	
	Following the whole class discussion, Mr J explained how to use the portable microscope. The student started to explore slides of organisms, using the microscope in the SPARKLE kits. Besides looking at the slides, students were exploring other objects they were interested in.	**Using portable microscope and slides from SPARKLE for exploration**
	 **Observing slides of bacteria and fungi on iPad guided by Activity Book**	
Communicating observations through text	After students examined the slides under the microscope, Mr J facilitated a whole class discussion. He asked everyone if bacteria and fungi were microscopic. Following students’ concurrence that bacteria and fungi were microscopic, Mr J affirmed their responses and reminded the class to record their observations.	**Recording observation, using the scaffolding in Activity Book**
	 **Using the Activity Book to record observations**	
	Upon completion of slides A, B and C on bacteria, Mr J told students to work on slides D, E, and F on fungi. Students focused on “identifying” what they saw. To focus students on describing their observations, Mr J provided them with scaffolds in the form of helping words.	

Mr J's Class – Increasing Student Agency in Exploring and Gathering Evidence		
Curricular Intent		**Resource Use**
	Consolidation	
Consolidating learning of bacteria and fungi	Mr J told the class that he hoped that they found observing bacteria and fungi a fun activity. He summarised that the students have learnt about some bacteria and fungi through the SLS video. He asked students to watch the penicillin video and to complete the Activity Book in their pairs as part of the consolidation for the lesson.	**Referencing SLS video to recap concepts learnt**

Planning and Reflecting Using the Content-Student-Resource Cycle



The microscope enabled students to observe the world of “invisible” organisms and objects. The exploration followed by discussions with peers and Mr J allowed students to compare their mental models of microorganisms with the expressed model (Byrne, 2011) depicted by their peers and Mr J through pair work, whole class discussion and recording of their observations in the Activity Book. Observations made in this activity allowed students to confront their initial ideas of the characteristics of microorganisms and through discussions with peers, formed more informed ideas of what microorganisms looked like. In Mr J’s class, the tool (microscope) formed the core of the lesson as students used it to observe things around them. The secondary tool used to make students’ ideas of their observation visible was SLS. These two tools framed the structure of the lesson and the interactions between students and Mr J. In this lesson, what was valued as evidence to shape students’ ideas about microorganisms were empirical observations (McNeill & Berland, 2017).

References

Byrne, J. (2011). Models of micro-organisms: Children’s knowledge and understanding of micro-organisms from 7 to 14 years old. *International Journal of Science Education, 33*(14), 1927-1961. DOI: 10.1080/09500693.2010.536999.

McNeill, K. L., & Berland, L. (2017). What is (or should be) scientific evidence use in K-12 classrooms? *Journal of Research in Science Teaching, 54*(5), 672-689. DOI: 10.1002/tea.21381.

Ruiz-Gallardo, J. -R., & Panos, E. (2018). Primary school students’ conceptions about microorganism. Influence of theoretical and practical methodologies on learning. *Research in Science & Technological Education, 36*(2), 165-184. https://doi.org/10.1080/02635143.2017.1386646.

C2. Check Your 'Special' Book

One key idea in the theme of Diversity is that objects around us are made of different types of materials that have different properties and functions. The properties of materials afforded their application and use under different conditions.

In this chapter, Mdm F facilitated students' construction of the concept of properties and uses of materials. She engaged them with experiences such as naming the materials used to make various objects around them. By emphasising the skills of comparison, students were introduced to objects with similar functions but made of different materials. Mdm F worked with her class of Primary 3 students by developing language competencies to appreciate the great diversity of materials and their application in everyday objects.

Primarily, students examined various pairs of objects made from different materials from the SPARKLE kits. They also made comparisons and recorded their ideas in the Activity Book. Students were encouraged to refer to the Textbook should they be uncertain of how to spell specific words to express their ideas or should they need to check up the properties of various materials. Mdm F reminded students that the Textbook would help them to communicate their ideas. By harnessing different resources, Mdm F orchestrated a multi-modal learning experience that was characterised by interactions between student-resources, student-student, teacher-student, and teacher-resources.

Mdm F's Class – Developing Language to Communicate Observations

Curricular Intent		Resource Use
	Capture	
	Mdm F started the lesson by reminding students about the choice of materials in building houses from the SLS video on "Three Little Pigs" that she assigned.	**Using SLS to prepare students for lessons**
	She proceeded to remind students that they previously carried out several activities on materials and asked students to refer to the Activity Book if they could not remember. She narrated how they identified objects around them, examined objects in their pencil cases, and worked together with their friends during group work while comparing materials. She reminded them of the questions they asked such as the number of materials that various objects are made of, and whether they are made of one, two or three materials. She recalled a student whose pen was made up of three different materials. To help students recall their SPARKLE experience in the previous lesson, Mdm F used questions to help students re-state the idea that "same objects … can be made up of different materials".	**Using Activity Book to recall learning experiences on materials**

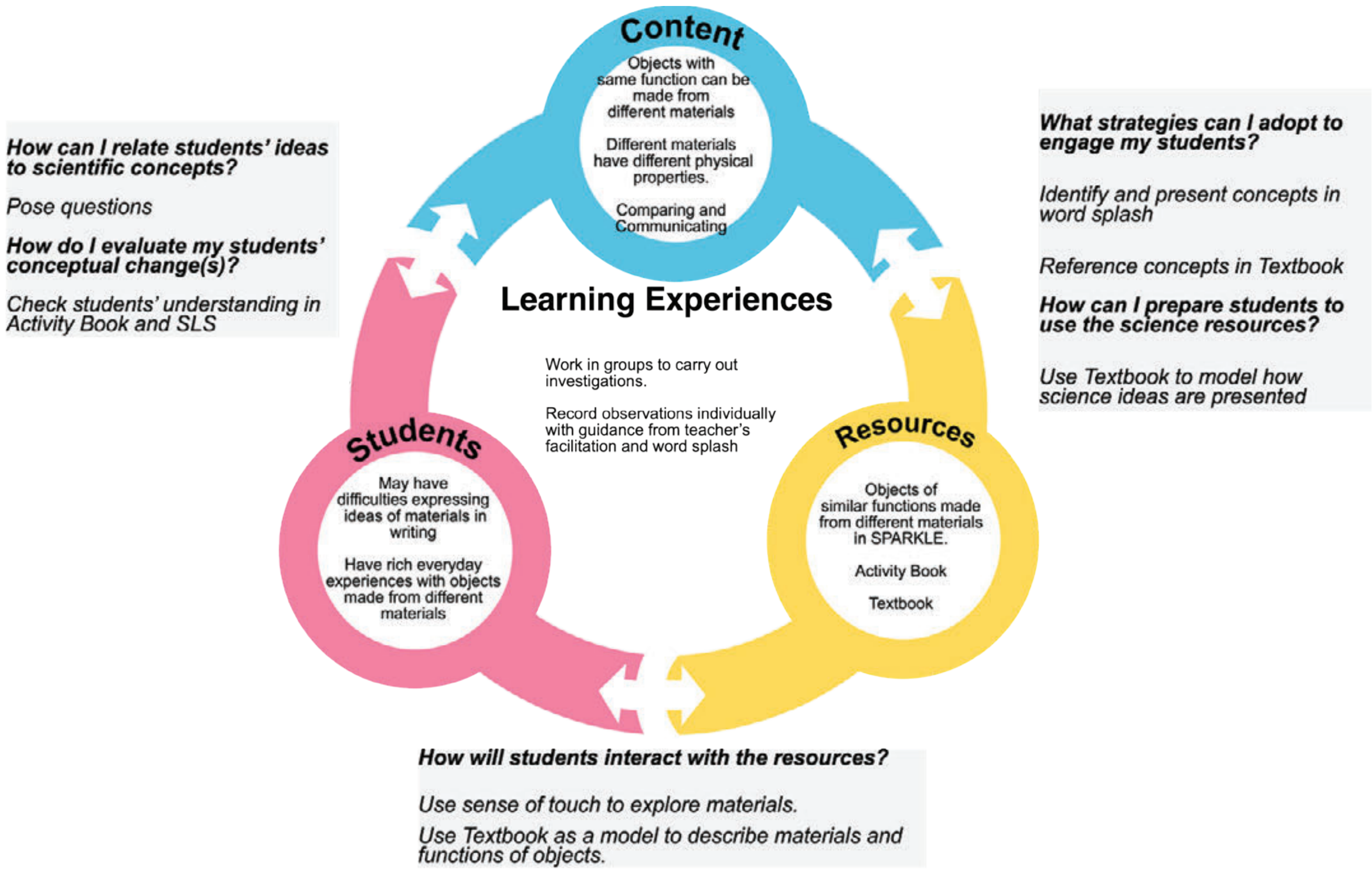
Mdm F's Class – Developing Language to Communicate Observations		
Curricular Intent		**Resource Use**
Harnessing students' prior conceptions and using them as starting points for the upcoming investigation	Mdm F then explicitly told students that they would still be working with the SPARKLE kits, but she would like to share some interesting ideas that students entered in the SLS first. Mdm F moved on to help students learn scientific vocabulary related to materials. She said, "The different words, hard, soft etc. they are the WHAT of materials? Starts with a "P." With these prompts, the students replied, "property". Mdm F continued to show other students' responses from SLS. Putting their ideas in public space for discussion was an important practice of science.  **Sharing students' ideas of materials in public space**	**Referencing SPARKLE experience to compare objects being made of different materials**
Communicating properties of materials	Following the whole class review using SLS, Mdm F repeated that students would be observing materials from the SPARKLE kits. Mdm F reminded them that they should use their five senses to make observations and classifications.	**Using SLS to share students' ideas**
	Construct Mdm F first distributed the SPARKLE kits to each group. Students promptly cleared their tables and explored the SPARKLE kits on their own. The students settled into their group work with ease as they knew their respective roles within their groups.	
Conducting investigations - observing different materials	Once the students were settled within their groups, Mdm F instructed them to refer to the activity entitled "Let's group them!" in the Activity Book. Mdm F projected the aims, materials and procedures required for the activity on the PowerPoint slide. She also highlighted where the procedure could be found in the Activity Book and instructed the class to read individually. All the students settled in to read. The visual instructions through the slide and Activity Book complemented the verbal instructions to support students' exploration.	**Using Activity Book and Word Splash to guide students' investigation of materials**

Mdm F’s Class – Developing Language to Communicate Observations

Curricular Intent		Resource Use
	For instance, she reminded the students to circle the words ‘similar’ and ‘different’. She also guided them in recording their observations with helping words on the whiteboard.	
	 **Preparing students for exploration of materials**	
	Further, Mdm F reminded students to look up the Textbook, Activity Book or the word splash on the board if they needed help. While students were working in their groups, Mdm F was guiding students one group at a time. When Mdm F noticed that some students had difficulties spelling some words, she reminded them to take out their ‘special book’ (Textbook). Students were often observed referencing the Textbook for ideas.	**Using Textbook as reference to communicate ideas on materials**
	Besides referencing the Textbook, students used their sense of touch to compare similar objects made from different materials.	
	 **Exploring different materials with sense of touch**	
Conducting investigation – classifying materials in different ways	For students who completed the comparison and recording of observations in their Activity Book, Mdm F challenged them to re-classify the materials in another way.	

Mdm F's Class – Developing Language to Communicate Observations		
Curricular Intent		**Resource Use**
	 Classifying materials in different ways	
Communicating ideas of classification in public spaces	***Consolidate*** Mdm F facilitated a whole class discussion and co-constructed together with the students three ways to group objects on the screen. Using questions, Mdm F also showed students' classification on the screen. As the lesson came to an end, Mdm F instructed the students to return the objects to the SPARKLE kit box. While the students were given the whole SPARKLE kit, they only took the materials they needed and replaced them after use. Students showed agency and a sense of responsibility to care for the resources provided to them.  Packing SPARKLE resources after use For the exit ticket, Mdm F asked the students to reflect on what they had learnt. They highlighted that they learnt about materials, specifically the grouping of materials based on function. To reinforce students' learning, Mdm F reminded them to read the Textbook to consolidate their learning and watch the SLS video to prepare for the next lesson on classification of objects.	**Learning responsible ways to use science materials in SPARKLE** **Reading Textbook and watching SLS video as reinforcement of learning and as preparation for next lesson**

Planning and Reflecting Using the Content-Student-Resource Cycle



Language that is "used as a tool to enable teachers and students to exchange ideas during interaction forms the fundamental basis for adopting a sociocultural perspective to examine classroom interactions since language systems are social and cultural artefacts" (Tan & Tang, 2019, p. 547). Language is not just the ability to speak or write but consists of a system of meaning-making resources (Halliday, 1978). For students to engage meaningfully with others during science learning, they must be able to communicate their ideas in an unambiguous and logical manner. Vygotsky (1962) opined that language provides the means for groups of individuals to think together. In the absence of language, ideas and thoughts are transient and cannot be reproduced in other contexts as there is no 'carrier' for the ideas.

Consequently, connecting students' observations and experiences to ways of communicating the observation is a crucial step in learning. The tool of choice to facilitate connection between students' observations and language development for sense-making and communication is the Textbook. The Textbook is a means through which students interact with the authors' ideas and learn from the authors. By consulting the Textbook, students learn how to express their ideas in a scientifically legitimate manner with appropriate vocabulary and expression.

References

Halliday, M. A. K. (1978). *Language as social semiotic: The social interpretation of language and meaning*. London: Edward Arnold.

Tan, A.-L., & Tang, K. S. (2019). The role of dialogue in science epistemic practices. In N. Mercer, R. Wegerif, and L. Major (Eds.), *The Routledge International Handbook of Research on Dialogic Education* (pp.547-558). Routledge.

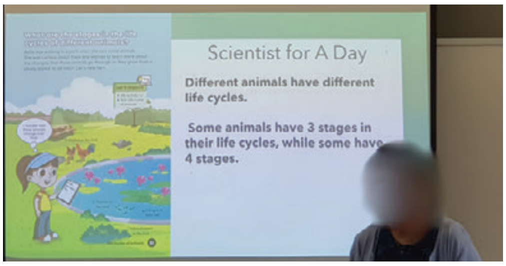
Vygotsky, L. (1962). *Thought and language*. Cambridge, MA: MIT press.

C3. We Can Wiggle Like a Worm

Teaching the life cycles of animals can be challenging as it involves complex biological processes that can be difficult to observe in real life. In the classroom, images or diagrams of the various life cycle stages are often used. These static images or representations may be difficult for young learners to understand as they could seem abstract or disconnected. As such, other modes of representation such as videos are used to supplement students' learning to demonstrate changes in the life cycle, such as the transformation of a caterpillar into a butterfly, that are otherwise difficult for students to directly observe. Furthermore, life cycles are also affected by ecological factors such as an animal's habitat, seasonal changes, and more. While real-life examples such as mealworms can be easily sourced, we usually observe the life cycles of unfamiliar animals through visual representations.

In this story, we explore how Mrs L used various modes of representation to (1) teach her students about the different life cycles of animals and (2) assess her students' learning through embodied experiences of role play to simulate each stage of a chosen life cycle.

Mrs L's Class– Engaging in Embodied Experiences through Role Play

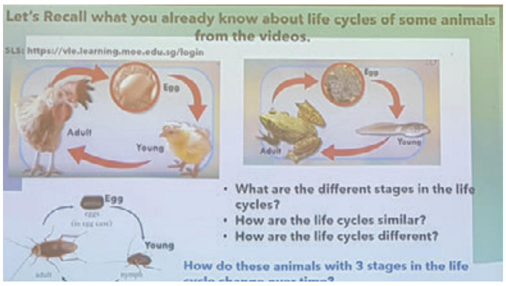
Curricular Intent		Resource Use
	Capture	
	To establish the learning outcomes and expectations, Mrs L began the lesson by introducing the learning objectives, emphasising that students would identify the life cycles of frog, chicken, and cockroach, compare the similarities and differences between the young and adult animals of different life cycles, as well as understand that the life cycles are repeated patterns of change. In addition, she shared her expectation that students should be able to demonstrate their learning by drawing the life cycles of these animals.	**Using Textbook to communicate learning outcomes**
		**Using the soft-copy Textbook in Teacher's slide**
Posing questions to elicit prior knowledge	To activate students' prior knowledge, Mrs L asked, "How do these animals change over time?" Student J shared that the chicken eggs would take time to hatch before going on to the next stage, while student Y expressed that the egg would change because it would grow. Mrs L built on their responses by probing further, asking, "How will you see that the animal has grown?" Upon hearing the response "by the looks and the size", Mrs L invited her student to elaborate further, providing students with the opportunity to think more deeply. This resulted in student R noting that the animal would "look older" at stages 2 and 3 of its life cycle.	

<table>
<tr><th colspan="3">Mrs L's Class– Engaging in Embodied Experiences through Role Play</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td>Surfacing and debunking a common alternative conception

Encouraging critical thinking</td><td>This surfaced the common alternative conception that the stages of a life cycle can be numbered. Mrs L took this opportunity to debunk this alternative conception by encouraging her students to share thoughts on why the stages should not be numbered. She then highlighted student Y's response that life cycles are continuous, as such they do not have a start or end point. She supported her statement by taking students through the life cycle of a mealworm, tapping on their recent personal experience and observations in caring for their mealworms by (1) probing them to consider what gave rise to the mealworm egg, (2) recalling the stages observed, (3) looking at one of their mealworm samples.</td><td>Using live mealworm for observation and discussion</td></tr>
<tr><td></td><td>Construct</td><td></td></tr>
<tr><td>Using multimodal representations of life cycles to reinforce and concretise students' learning

Communicating - Making sense of information</td><td>Next, Mrs L showed screenshots taken from the SLS video on the life cycles of chicken, frog, and cockroach. She used these examples to illustrate the similarities and differences between the young and adult of the 3-stage life cycles, asking students to describe how the characteristics of animals have changed.

Mrs L then played one of the SLS videos on life cycles and paused from time to time to further reinforce students' understanding of how animals change through their life cycles. For example, she drew students' attention to the arrows showing the continuous movement and change from one stage of the life cycle to another.



Highlighting screenshots of the life cycles of three animals from SLS Video

Mrs L then assigned students to work on the Activity Book, reminding them to refer to the Textbook if they had questions. In this activity, students named the stages in the life cycles of cockroach, chicken, and frog, drew arrows to indicate the direction of change, and compared whether the young of the animal looked similar/different from the adult.</td><td>Using screenshots of life cycles of cockroach, chicken and frog from SLS video to facilitate comparison</td></tr>
</table>

Mrs L's Class– Engaging in Embodied Experiences through Role Play

Curricular Intent		Resource Use

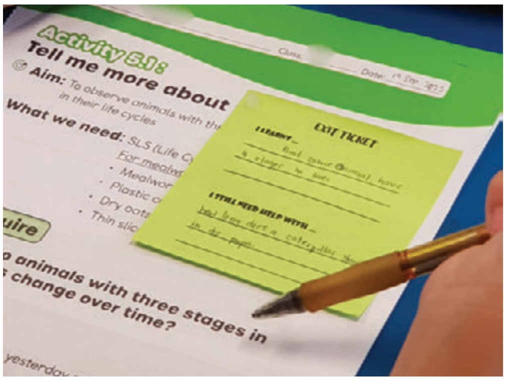
Consolidate

Collecting evidence of students' learning

Lastly, Mrs L checked her students' understanding on life cycle in two ways. Firstly, she handed out Post-its as exit tickets for students to write down what they have learnt and ask any questions they still had. Secondly, students worked in groups of three or four to choose an animal and then planned how they would enact the stages in its life cycle for their classmates who would guess the correct stage being performed in the next lesson.

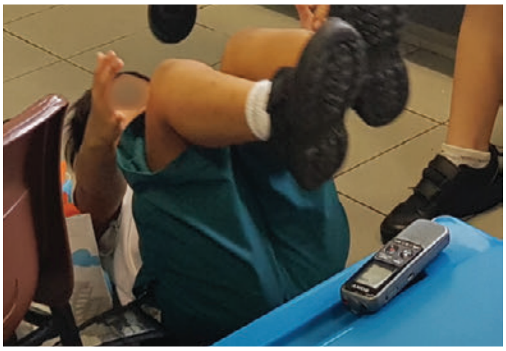
Experiencing embodied learning experiences through social interaction in role play

Students formed their groups and discussed life cycles enthusiastically. While some wiggled their bodies to represent the young (larva) of a mealworm beetle, others took to the floor crouched in position to represent the egg or moved their bodies to represent the caterpillar. The students actively engaged with each other as they determined the best way to represent the stages in the life cycle of an animal of their choice.



Assessing students' learning through "Exit Ticket"

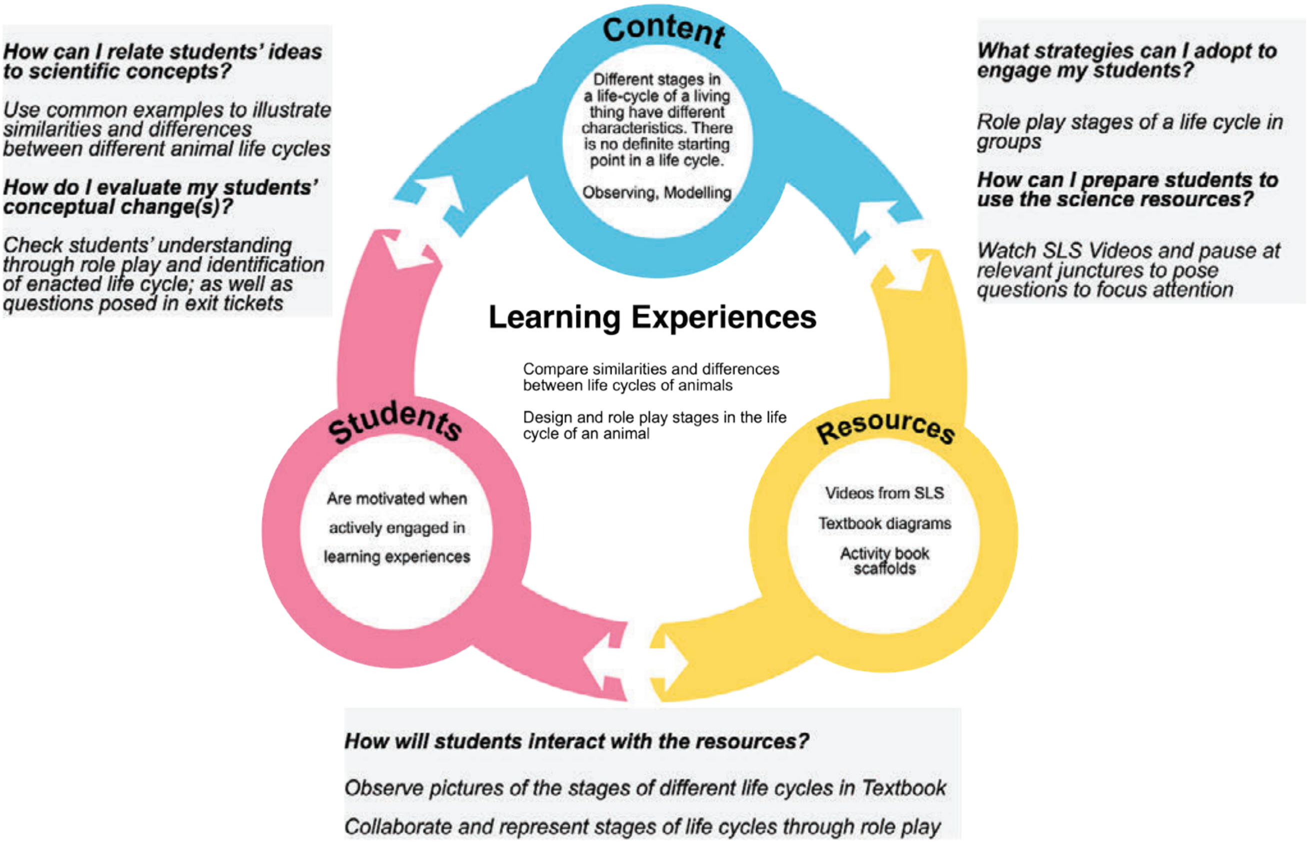
Using Activity Book and Post-Its (exit tickets) for consolidation



Role modelling a stage in the life cycle of an animal

Mrs L concluded her class by sharing a student's response in the exit ticket and informing the class that they would enact their chosen life cycle and stage for their peers to guess in the next lesson.

Planning and Reflecting Using the Content-Student-Resource Cycle



Role-playing involves acting out a specific function or part of an entity. It is a common teaching strategy that is widely used in the creative arts, literature or social studies. In science learning, role-playing can be used to develop students' ability to observe living things and depict them to accurately communicate their forms and behaviours. Engaging young learners in role-playing offers opportunities for them to develop skills of taking initiatives, communicating their ideas, problem-solving, being self-aware, and working cooperatively in teams (Craciun, 2010).

As observed in Mrs L's classroom, during the role-playing activities, students made use of their knowledge of insect life cycles learnt earlier and applied them to make decisions on how they would represent the wiggling larval stage of the insect. Students also wondered how they could represent the egg of the insect since it does not move. Through discussions and negotiations with their peers in the same group, students practised defending their ideas with evidence, illustrating their inventive thinking, communication, and collaboration. Students also had fun—evidenced from the higher noise levels from laughter—and were cognitively engaged.

Role-playing was only possible because Mrs L has equipped students with the necessary knowledge and ideas related to life cycle. Mrs L identified potential alternative conceptions (starting and ending of life cycle) and intentionally raised them as questions for whole class discussions. She used videos and diagrams from SLS and the Activity Book to focus students' attention as they learnt the concepts.

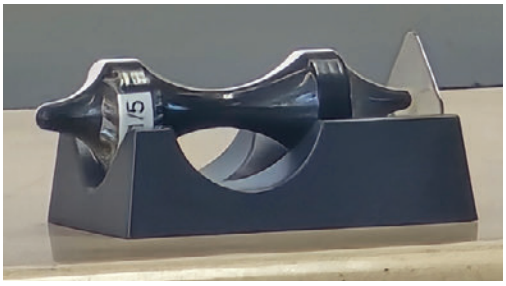
Reference

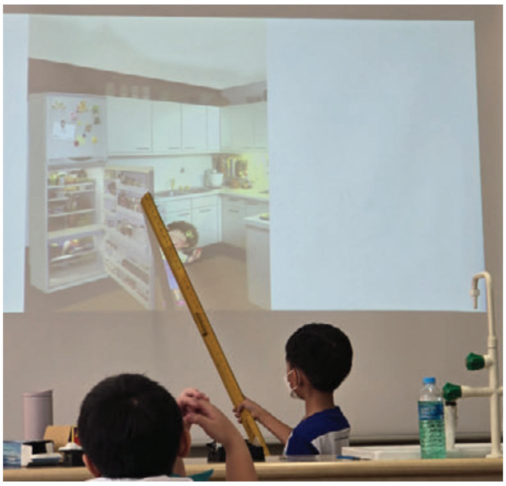
Craciun, D. (2010). Role-playing as a creative method in science education. *Journal of Science and Arts, 1*(12), 175-182.

C4. Attract or Repel?

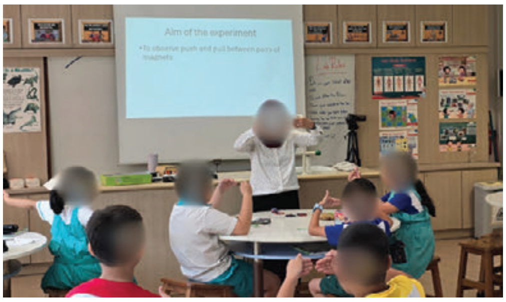
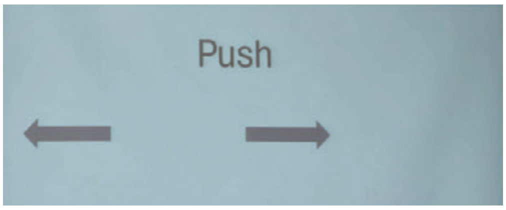
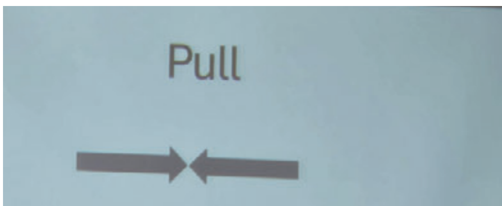
Playing with magnets is an enjoyable experience for students as they observe how magnets interact with other magnets and materials in different types of toys and everyday objects. As magnetic forces are invisible, observing the effects when magnets interact with other objects is fascinating for young learners. Common alternative conceptions here include “all magnetic materials are magnets” and “objects are magnets if they can be attracted”.

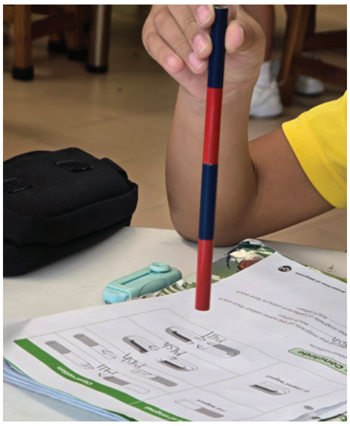
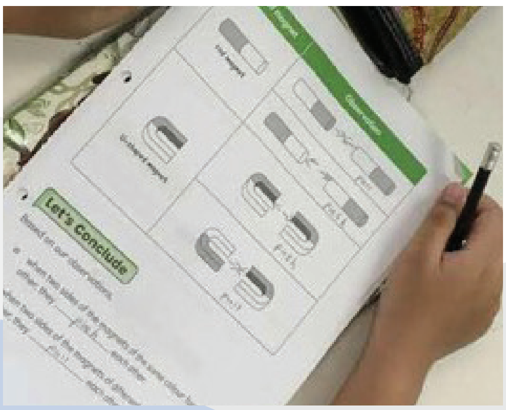
In this chapter, we join Miss F’s class to appreciate how she provided opportunities for Primary 3 students in using movement, hands-on activities, annotation to experience and explain interactions between magnets. In her lesson plan, Miss F indicated that she hoped that through the lesson, students would appreciate the use of magnets in everyday applications, and be able to observe, explore, and describe how different types of magnets exert push or pull.

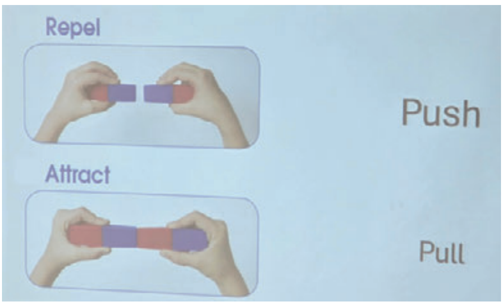
Miss F’s Class – Attract or Repel: Multiple Representation and Embodied Experiences		
Curricular Intent		**Resource Use**
	Capture	
	Miss F piqued the students’ curiosity by showing a physical levitating toy. She passed Student A’s ruler between the toy and magnet, and showed how she could turn the toy freely. Students chorused excitedly, “Magnet! Woo!”.  **Observing a levitating toy**	**Using teacher-sourced artefacts for demonstration**
Appreciating core idea of interaction through observation and discussion	Next, Miss F showed a levitating globe on the slides and asked students why the toy could “spin” in the air. “Levitating! Floating!”, Students B and C responded sequentially.  **Observing a levitating globe**	

Miss F's Class – Attract or Repel: Multiple Representation and Embodied Experiences		
Curricular Intent		**Resource Use**
Connecting application of magnets to everyday experiences	Miss F highlighted that the similar observations between the levitating toy and globe were due to magnets. After the whole class observation and discussion of levitating toy and globe, Miss F shared that magnets are found everywhere and hence the class was learning about magnets. She showed a picture of electrical appliances including a computer on the slide and elicited other examples of uses of magnets. "Phone, refrigerator, television!", several students cited examples spontaneously one after another.  **Discussing uses of magnets in electrical appliances**	
Developing vocabulary to communicate science ideas	Students went on to identify the location of magnets in selected appliances such as the refrigerator and explained how magnets worked. Miss F highlighted the concept of interaction between magnets. ***Student D:*** *Magnet and magnet stick together.* ***Student D:*** *Attract.* ***Teacher:*** *You need how many magnets to work?* ***Student F:*** *Two.* ***Teacher:*** *The two magnets interact…*	
	Construct	
Sequencing learning experiences meaningfully, to understand the interaction of magnets in different ways	Miss F introduced the SPARKLE Kit. Before starting the investigation, she revisited Student D's and Student E's observations of "magnets sticking" and "attracting" each other respectively. Miss F noticed and complimented Student F for using a hand movement to show attraction (bringing two hands together).	**Preparing for investigation using SPARKLE**

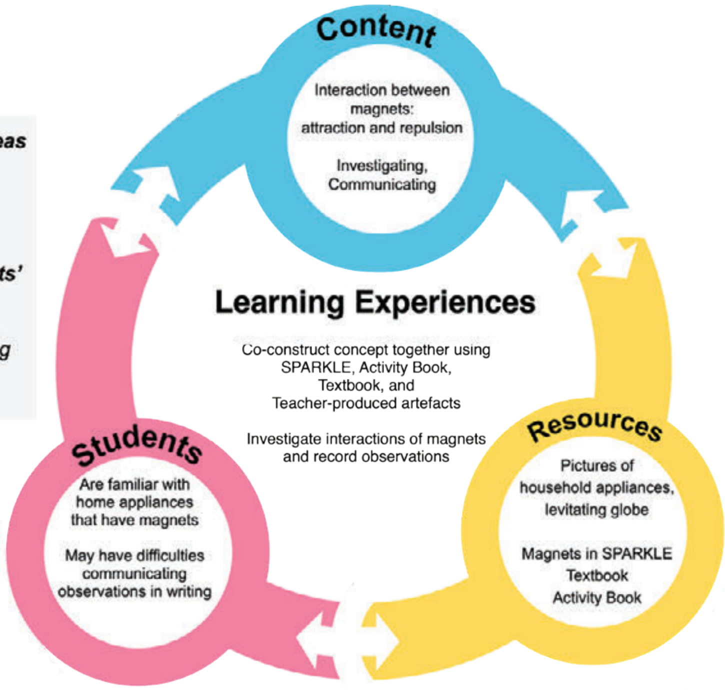
Miss F's Class – Attract or Repel: Multiple Representation and Embodied Experiences

Curricular Intent		Resource Use
	Body Movement. Miss F shared that students would be investigating "push" and "pull" using the Activity Book. She asked students to show her what "pushing" and "pulling" meant, imagining their hands as magnets. Seeing mixed responses from the class, Miss F invited two students to demonstrate "pushing" and "pulling". After the demonstration with two students, Miss F invited the whole class to use their hands to show "pushing" and "pulling".  Learning to show a 'push'  Learning to show a 'pull' **Slide Animation.** After the hand movement, Miss F showed a slide animation of arrows (representing magnets) moving away from each other (push) and moving towards each other (pull).  Representing 'push' in a diagram  Representing 'pull' in a diagram	**Using body movements and slide animation to understand "pull" and "push"**

Miss F's Class – Attract or Repel: Multiple Representation and Embodied Experiences		
Curricular Intent		**Resource Use**
	Hands-on Exploration. Following the whole class body movement and slide animation, students started exploring how each pair of different magnets (bar, ring, rod, U-shaped) interacted using both the SPARKLE kit and Activity Book. Miss F observed and complimented her students for playing with magnet creatively.     Exploring and observing interaction of magnets	Hands-on exploration using SPARKLE and Activity Book
Representing interactions of different types of magnets in diagrams	**Annotation.** Next, Miss F introduced concepts of "interaction", as well as "arrows to show the direction of push and pull". Using a pair of bar magnets, she also guided students to draw and annotate the arrows (push or pull) as students recorded their observations of magnet interactions. Then, students went on to observe, draw and annotate arrows for other pairs of magnets (button, rod, U-shaped).  Representing observations using Activity Book	

Miss F's Class – Attract or Repel: Multiple Representation and Embodied Experiences		
Curricular Intent		**Resource Use**
Using questions to connect observations and concepts of attraction and repulsion	Besides observing the interactions of the magnets, Miss F also asked students if the magnets pushed or pulled each other when the same-coloured parts of two magnets faced each other. "Pushed!", students chorused. She also facilitated discussion of different coloured parts of two magnets facing each other resulting in "pulls". She also asked students why some students did not see any interaction when certain parts of the magnets were put near each other. This led to the introduction of the concept of "poles of magnets".	
	Consolidate Miss F summarised students' observation and description of interactions of magnets through investigation using SPARKLE. She highlighted how magnets interact and referred to students' initial ideas of magnets sticking to each other but have now learnt that magnets "push" or "repel" as well as "pull" or "attract". She encouraged her students to read the Textbook to reinforce what they have learnt in class.  **Referencing Textbook to consolidate learning**	**Using Textbook to consolidate learning**

Planning and Reflecting Using the Content-Student-Resource Cycle



How can I relate students' ideas to scientific concepts?

Use familiar examples of household appliances with magnets

How do I evaluate my students' conceptual change(s)?

Check students' understanding through verbal responses during whole class and group verbal discussions; individual written responses and annotations

What strategies can I adopt to engage my students?

Body-based gestures to embody direction of attraction and repulsion

Hands-on investigations to experience attraction and repulsion

How can I prepare students to use the science resources?

Question to elicit prior knowledge on interaction of magnets

Model the interaction using bar magnets before investigating interactions of other magnets

Show direction of attraction and repulsion using animated slide before annotating

How will students interact with the resources?

Carry out guided investigation using SPARKLE and Activity Book

Use gestures, animation and annotation to learn direction of attraction and repulsion.

In this lesson, students explored and described the interactions of magnets, beginning with ideas of “magnets sticking to each other” and “magnets pulling each other”, and eventually developed concepts of “magnets attracted to each other”. This illustrates what Vygotsky (1934/1994) described as the nature of concept development, beginning with spontaneous concepts and eventually “scientific” concepts. The progress of language from common everyday language to more specialised use of attraction of magnet is evidence of growth in scientific knowledge and the process is facilitated by both the teacher and the resources. In this example, the teacher and the resources serve as mediators of learning to enable students to move in the zone of proximal development.

Examining the pedagogical and resource considerations across the entire lesson, Miss F started the lesson with a physical levitating toy and pictures of everyday appliances that students could relate to. She facilitated a whole class discussion, eliciting students’ observations of magnets, progressing from “sticking”, to “pulling”, and finally to “attracting”. Both the physical toy and pictures have scaffolded students in articulating their ideas on how magnets interact, such as “magnets sticking to each other” to allow the refrigerator door to close.

While Miss F began the lesson with a more teacher-guided whole class discussion to engage students in talking about interaction between magnets, she designed a more student-centred hands-on exploration in the next part of the lesson using the SPARKLE kit. Students explored different pairs of magnets such as bar, ring, rod, U-shaped magnets in groups of four. After the hands-on exploration of interactions of different magnets, teacher guided students in recording their observations of magnets “pushing” and “pulling” in the Activity Book. Guided by the diagrams of magnets, each student not only identified the interaction as “push” or “pull”, but also annotated the direction of movement of magnets with arrows. This gradual move from teacher-guided to student-centered teaching strategies or a mixture of both is found to be useful for students’ success in learning scientific practices (Bell et al., 2005). During the group discussion, students explored different ways of arranging the magnets to observe and describe the patterns of interactions. In a review of 2008–2017 studies on teaching strategies for scientific practices, Suarman et al. (2020) found that “experimenting” and “discussing”, and a combination of experimenting and discussing were the most used teaching strategies to achieve cognitive and affective teaching goals.

Besides the intentional design of teacher-guided and student-centred learning experiences, it is interesting to observe teacher’s inclusion of embodied experiences to support students in appreciating interactions of magnets. The planned experiences of “moving hands to experience the pull and push between magnets”, to “observing animation of magnets”, to “playing with SPARKLE magnets” have supported students in their final tasks of “annotating diagrams with texts (pull and push) and arrows showing magnet interaction” in the Activity Book. The design considerations in this study are supported by the two-dimensional taxonomy developed by Skulmowski and Rey (2018). Their taxonomy included “bodily engagement” (i.e. how much bodily activity is involved) and task integration (i.e. whether bodily activities are related to a learning task in a meaningful way or not).

References

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher, 72*(7), 30–33.

Skulmowski and Rey Cognitive Research (2018). *Principles and implications, 3*(6), https://doi.org/10.1186/s41235-018-0092-9

Suarman, H, Hsu, Y.-S., Zhang, W. X., Kuo, Y.-R., & Wu, J.-Y. (2020). Features and trends of teaching strategies for scientific practices from a review of 2008–2017 articles, *International Journal of Science Education, 42*(7), 1183-1206.

Vygotsky, L. S. (1934/1994). The development of academic concepts in school aged children. In R. van der Veer & J. Valsiner (Eds.). *The Vygotsky reader* (pp. 355-370). Oxford: Blackwell.

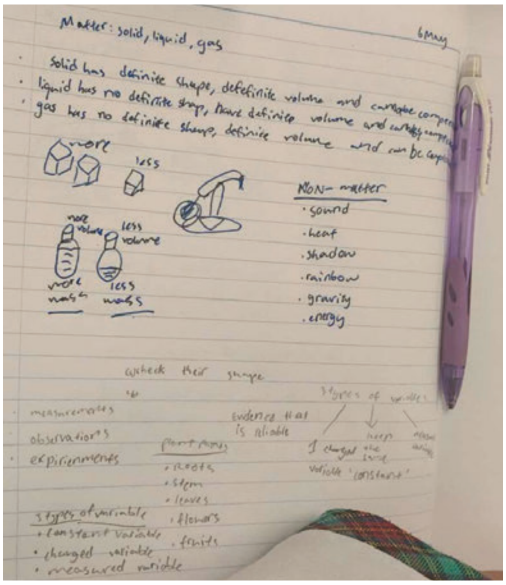
C5. Same Volume, Same Mass: Think Again!

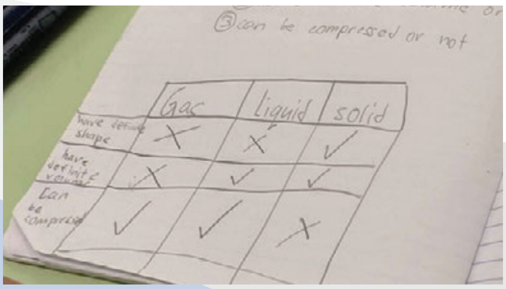
In the topic of matter, students learn about the three states of matter and their observable properties. Knowing the three states of matter forms the foundation for understanding the particulate theory of matter at higher levels of study in science. The topic also introduces students to the scientific practice of accurate measurement of mass and volume using appropriate tools. In this chapter, Ms A provided opportunities for her students to investigate if objects of the same volume have the same mass by tapping on technology to make her students' thinking visible.

To carry out scientific investigations, students posed questions, designed and conducted the investigations. In designing and conducting investigations, students learn to formulate hypothesis and also choose appropriate scientific apparatus to collect data.

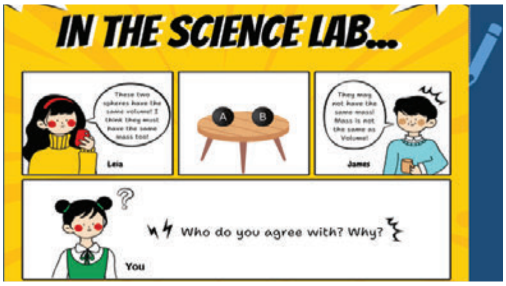
Ms A's Class – Same Volume, Same Mass? Sensemaking of Data

Curricular Intent		Resource Use
	Capture	
Encourage student agency in expressing prior knowledge and posing questions	Ms A facilitated students in recalling their prior knowledge on matter by jotting down "3-2-1" pointers in their Science Journal (3 ideas they remembered, 2 ideas they found interesting and wanted to find out more, 1 question they still have).	





Examples of students' notes in Science Journal

<table>
<tr><th colspan="3">Ms A's Class – Same Volume, Same Mass? Sensemaking of Data</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td>Communicating, evaluating and defending ideas with evidence</td><td>Ms A introduced a concept cartoon where two characters discussed if balls A and B of the same volume would have the same mass. Students discussed in groups, on which character they agreed with, and stating the reasons for their choices.


Using Concept Cartoon to facilitate discussion

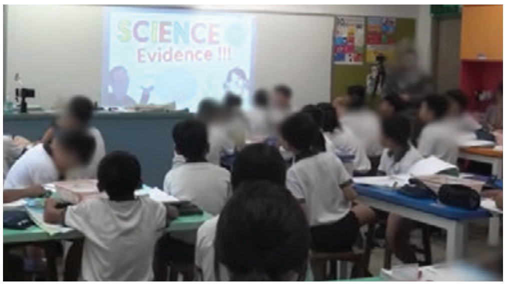
Ms A facilitated a whole class discussion on how the mass and volume of objects can be measured accurately.

Ms A: Who do you agree with?
Student: I agree with James. I can see the volume is the same, but the mass is different because the inside is not the same.
Ms A:Ok, you can see that the volume is the same. It is just visual. How can you find out that they have the same volume?
Student: Use a measuring cylinder.
Ms A: How about mass?
Student: Use a weighing scale.
Ms A:Ok, class, can someone add on about measurement of volume of solid? Do we use only measuring cylinders?
Student: We need water, then we need the volume of solid and water, then minus volume of water.</td><td>Using teacher produced Concept Cartoon to encourage students' discussion</td></tr>
<tr><td></td><td>Construct</td><td></td></tr>
<tr><td>Designing investigations</td><td>To find out which character in the concept cartoon was right, Ms A highlighted that a fair investigation should be conducted. She shared that an investigation was fair when any results collected was due to the changed variable. Ms A next played a video showing an investigation to determine the best soap to remove dirt from clothes. While the video was playing, students were encouraged to jot down notes in their Science Journal. Ms A also wrote key pointers on the whiteboard to guide students in thinking and recapping the three variables for the investigation: constant variables, changed variable, and measured variable.</td><td>Using Textbook, video and slides to strengthen understanding of processes in an investigation</td></tr>
</table>

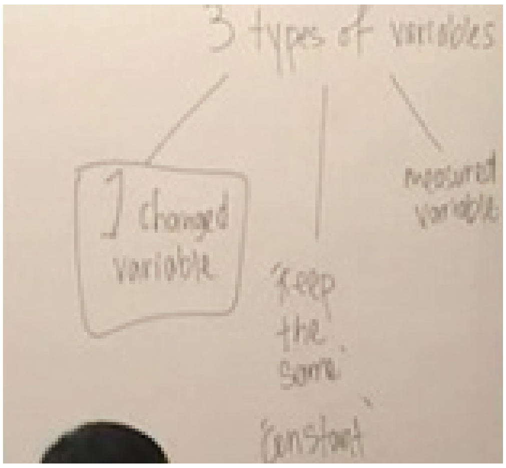
Ms A's Class – Same Volume, Same Mass? Sensemaking of Data

Curricular Intent

Resource Use



Preparing to work with evidence



Learning about variables

Ms A recapped the different types of variables shown in the video through class discussion:

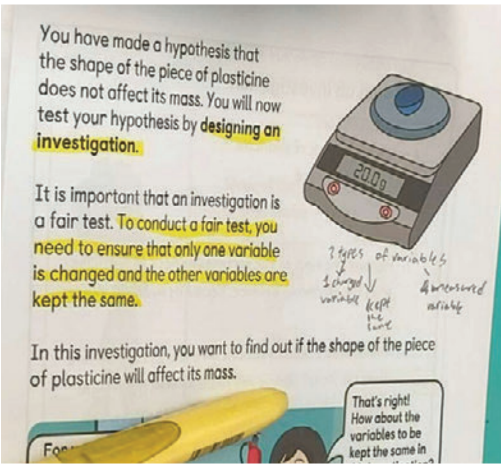
> ***Ms A:*** *What is the variable kept the same called?*
> ***Student:*** *Constant variable.*
> ***Ms A:*** *Yes, all the variables must be kept the same, with only one variable changed. What is that called?*
> ***Student:*** *Changed variable*
> ***Ms A:*** *Why is only one variable changed? This is to make sure results collected are due to that one changed variable. What are the results called?*
> ***Student:*** *Measured variable*

Ms A also reinforced the concept of hypothesis through classroom discussion:

> ***Ms A:*** *What is hypothesis?*
> ***Student:*** *Make a guess of what would happen?*
> ***Ms A:*** *Just a guess? Anyone wants to add on?*
> ***Student:*** *An educated guess?*
> ***Ms A:*** *Yes, an educated guess, not just a random guess. It is something you have information already on it. This is what scientists do; they have some information first.*

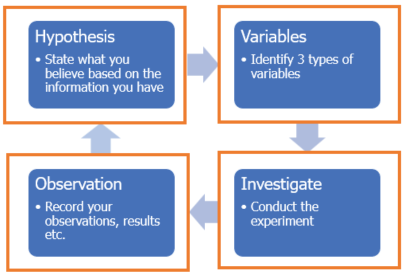
Ms A's Class – Same Volume, Same Mass? Sensemaking of Data

Curricular Intent		Resource Use
	Ms A invited students to share their hypothesis based on what was discussed in the concept cartoon shown earlier. Using the Textbook, Ms A highlighted and added notes on concepts related to a fair investigation such as hypothesis, constant variables, changed variable and measured variable. Students were encouraged to annotate their Textbook and modelled how it could be used for learning.	**Guiding students to use Textbook to facilitate learning on their own**



Annotating concepts in Textbook

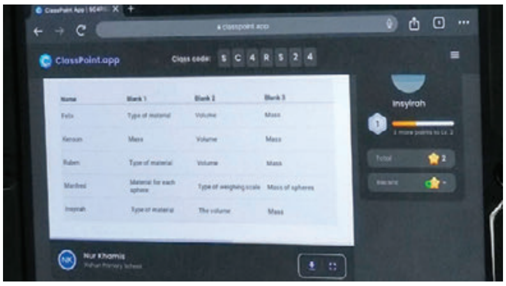
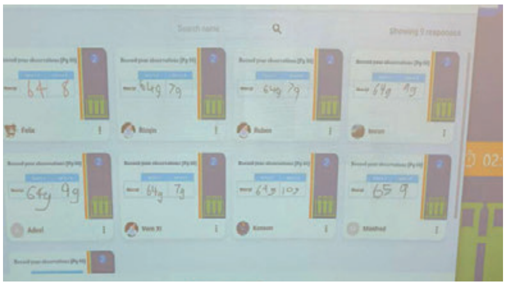
	To support students in appreciating the process of investigation, Ms A shared, "You begin with a hypothesis, then you identify your variables. Then, you investigate to observe, then back again if your hypothesis matches. If it does not match, check back again, and think if there could be another explanation."	**Using teacher-produced artefact to summarise process of investigation**

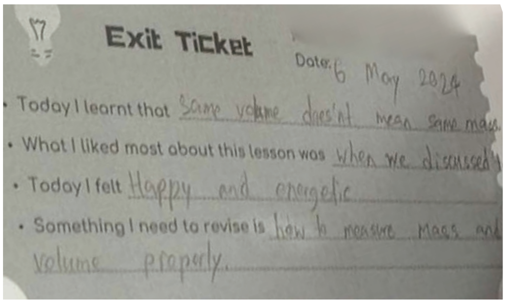


Showing slide on experimental process

From the hypothesis, Ms A invited students to share the variables related to their experiment (variables to be changed, kept the same, measured) using an ICT Tool.

Through this tool, students' thinking was made visible, where Ms A discussed different student responses. For example, in the discussion, Ms A highlighted the importance of clarity in responses.

Ms A's Class – Same Volume, Same Mass? Sensemaking of Data		
Curricular Intent		**Resource Use**
	 ICT tool for sharing students' ideas in public space	Assessing students' understanding of variables by making their thinking visible with an ICT tool
Conducting investigations analysing, and interpreting data	**Conducting Investigations.** Once students agreed on the different variables involved, students conducted the investigation following the steps in the Activity Book and using Balls A and B provided in the SPARKLE kit. Ms A reminded students on proper use of apparatus (e.g., tare the electronic balance before measuring mass of balls, place electronic balance on a flat surface).	
	Analysing and Interpreting Data. Students recorded their observations using the ICT Tool. Ms A facilitated a whole class discussion using the following questions: • What are the similarities in the class results? • What are the differences in the class results? The class concluded that although the volumes of both balls were the same, the mass of ball A was greater than ball B. The class also observed the masses recorded by groups differed slightly, which could be due to how the balls were weighed.	Using Activity Book and SPARKLE to scaffold investigation
	 Recording observations using ICT tool	
Comparing results among different groups before drawing a conclusion	Ms A referred students to their hypothesis, and whether their conclusion was the same as their initial hypothesis based on the evidence collected.	

Ms A's Class – Same Volume, Same Mass? Sensemaking of Data		
Curricular Intent		**Resource Use**
	Consolidate At the end of the lesson, Ms A recapped the investigation process and highlighted the importance of fair tests and accurate measurements. Students filled in exit tickets at the end of the lesson. This allowed Ms A to check for students' understanding for the whole lesson.  **Assessing learning through Exit Ticket**	**Providing opportunities for students to reflect on their learning through an exit ticket**

Planning and Reflecting Using the Content-Student-Resource Cycle

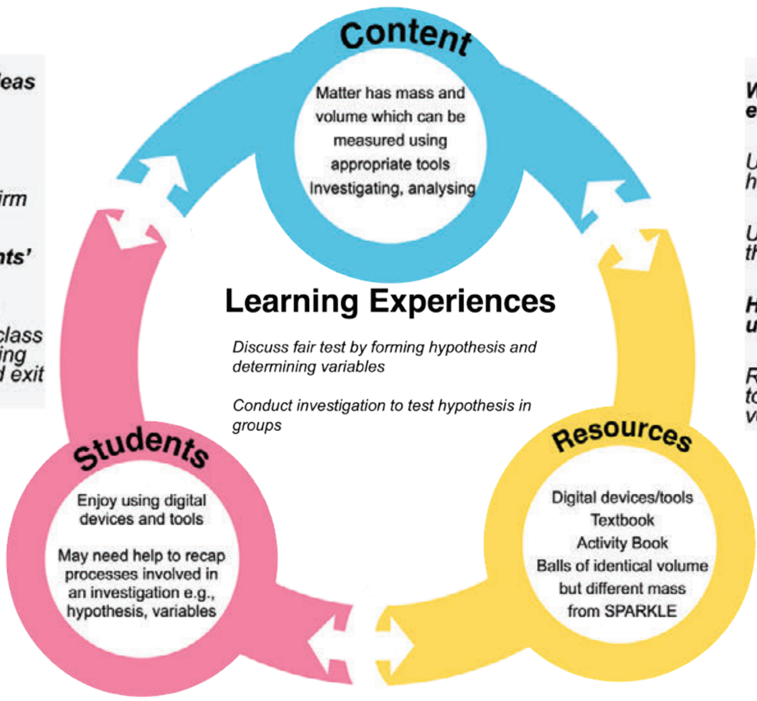
How can I relate students' ideas to scientific concepts?

Recap concepts of mass and volume

Conduct investigations to confirm hypothesis

How do I evaluate my students' conceptual change(s)?

Check students' concepts and understanding through whole class questioning and discussion using ICT tools; science journals and exit tickets



What strategies can I adopt to engage my students?

Use Textbook and videos to recap how to conduct a fair test

Use ICT tools to make students' thinking visible

How can I prepare students to use the science resources?

Recap the appropriate ways and tools to measure mass and volume

How will students interact with the resources?

Recap fair test through Textbook and Video

Conduct guided investigations using SPARKLE and record results in AB and ICT tools

The concept cartoon was used as a stimulus to elicit students' ideas about mass and volume and to set them thinking about how they can measure mass and volume of objects. The cartoon also scaffolded students in discussing how they can design an investigation to support their claims of which character from the concept cartoon is correct. To support students in designing the investigation and collecting data, Ms A guided the students through the process of hypothesis setting, ensuring fairness and comparability in collecting data. By discussing the process of investigation explicitly before the students engaged with the hands-on, Ms A not only prepared the students to confidently work with the SPARKLE kits but also primed them to conduct their investigations in a thoughtful manner. Research studies have found explicit instructions of inquiry skills (for example explaining experimental design, how data can be treated) to be more effective for fifth and sixth grade students in Dutch classrooms (Kruit et al., 2018) and in upper secondary students (Vorholzer et al., 2020).

References

Kruit, P. M., Oostdam, R. J., & Van den Berg, E. (2018). Effects of explicit instruction on the acquisition of students' science inquiry skills in grades 5 and 6 of primary education, *International Journal of Science Education, 40*(4), 421-441. DOI: 10.1080/09500693.2018.1428777.

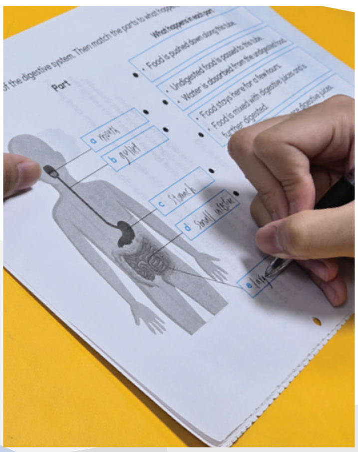
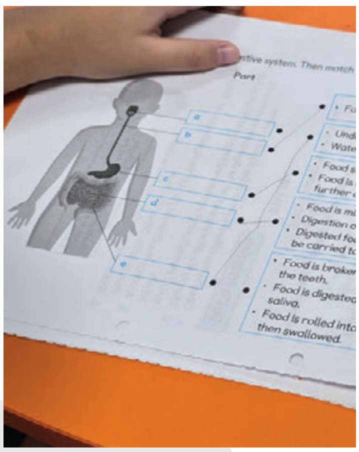
Vorholzer, A., von Aufschnaiter, C., & Boone, W. J. (2020). Fostering upper secondary students' ability to engage in practices of scientific investigation: a comparative analysis of an explicit and an implicit instructional approach. *Research in Science Education, 50*, 333-359. https://doi.org/10.1007/S11165-018-9691-1.

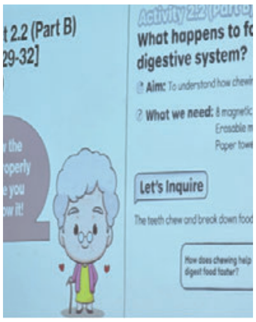
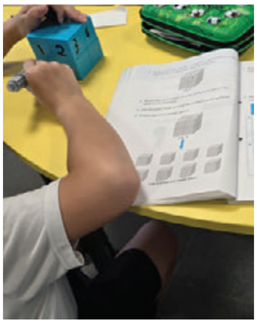
C6. Grandma says, “Chew your Food”. Is she right?

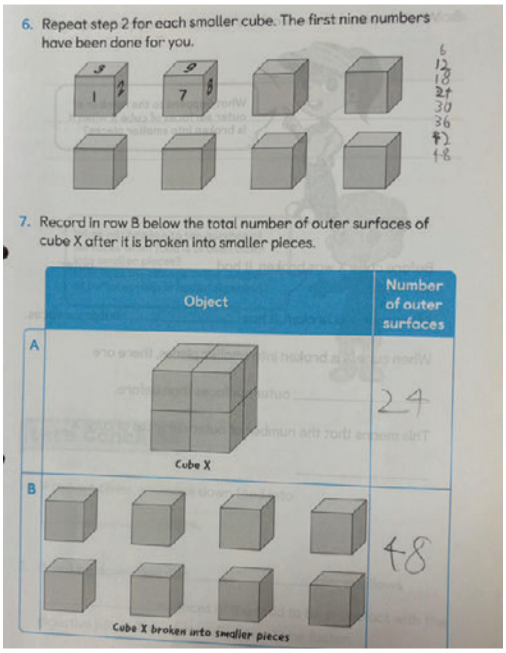
Learning about the digestive system in primary science has always been exciting for students as they discover how their body works. Of particular interest to students is how they can ‘see’ what is inside their body, make sense of familiar experiences such as chewing their food, and be able to explain their experiences in more scientific ways. A common alternative conception is that the human digestive system is two-dimensional. In this chapter, we enter Mr P’s classroom to understand how he led his class of Primary 4 students through hands-on modelling and personal examples to visualise the human digestive system and digestion of food.

<table>
<tr><th colspan="3">Mr P’s Class – Modelling and Understanding the Digestive System and Digestion of Food</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td></td><td>Capture</td><td></td></tr>
<tr><td></td><td>Mr P reviewed his students’ prior knowledge of the main functions of digestive system. “Breaking food into simple substances” and “gives us energy”, Students A and B shared. He elaborated on the role of digestives juices in saliva and highlighted that the lesson would focus on how food is absorbed.</td><td></td></tr>
<tr><td></td><td>Mr P revisited the arrangement of parts of digestive system on the SPARKLE kit apron by different groups. He asked how the model of digestive system aprons was useful in understanding the human digestive system. Students acknowledged that Mr P could not open up the body to show them the different parts.</td><td>Using SPARKLE to discuss usefulness and limitations of models</td></tr>
<tr><td>Posing questions</td><td>Mr P went on to discuss possible limitations of the model, “Do you think the model shows you exactly how the human digestive system looks like?”. “No”, “Not exactly”, Mostly”, a few students responded. Mr P probed deeper on why food needs to be broken down. “So that food has greater surface area”, “break into smaller pieces, digest faster”, a few students explained.</td><td></td></tr>
<tr><td></td><td>Construct</td><td></td></tr>
<tr><td>Connecting to everyday experiences</td><td>Next, Mr P introduced one of the class’s favourite food—pizza. He reminded students about their group activity with the SPARKLE apron and also showed a picture of himself wearing it. He asked students to imagine themselves as pieces of pizza travelling from the mouth to the large intestine.</td><td></td></tr>
</table>

Mr P’s Class – Modelling and Understanding the Digestive System and Digestion of Food

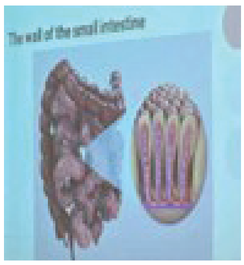
Curricular Intent		Resource Use
Visualising and modelling the human digestive system	Students chorused the parts of the human digestive system in sequence confidently, “Mouth, gullet, stomach, small intestine, large intestine”. He reminded students not to mix up “gullet” and “windpipe”, something he noticed in the last lesson.  **Visualising with SPARKLE**	
	To reinforce the parts and functions of the human digestive system, students were asked to look at a diagram of the human digestive system with a list of jumbled up functions in the Activity Book. Most students filled the parts before matching each part with its functions. A few matched the functions with the diagram of the human digestive system, before labelling the parts. After individual student work, the teacher went through the matched parts-functions as a whole class.   **Relating parts of digestive system to functions**	**Visualising digestive system with diagram in Activity Book**

Mr P's Class – Modelling and Understanding the Digestive System and Digestion of Food		
Curricular Intent		**Resource Use**
Posing questions	After matching the parts with their functions in the human digestive system, Mr P focused students on parts of the human digestive system where digestion happens. He also addressed earlier student S' question on what digestive juice was. He introduced the concept of "enzyme" which they will learn later in secondary school. Another student asked, "Why the stomach is not harmed by the digestive juice?". Mr P told the class that they could further discuss gastric pain in a later lesson. Mr P shared his grandma's advice to chew food before swallowing. In response, Student S shared her mum's cautionary advice on choking if she did not chew her food. After providing the authentic context for investigation, Mr P introduced the SPARKLE magnetic cubes, markers and procedures in the Activity Book to explore if his grandma and Student S' Mum were correct. In groups, students compared the surface areas of cubes (representing whole piece of pizza) before and after the cubes were "broken" into eight pieces.    **Relating surface area to volume** Following the group exploration, Mr P facilitated a whole class discussion on the number of surfaces they counted, before and after the cubes (pizza) were "broken" into pieces. When the food was "broken" into eight smaller pieces, there were more surface areas exposed to the digestive juices, increasing from 24 to 48. Mr P also highlighted the important role of teeth in breaking food into smaller pieces to facilitate swallowing. He also related to crushing medicine pills to facilitate eating and digestion. He and the class concluded that his grandma and Student S's Mum were correct.	**Modelling food digestion using SPARKLE**

<table>
<tr><th colspan="3">Mr P’s Class – Modelling and Understanding the Digestive System and Digestion of Food</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td>Making connections across maths and science on concept of surface area</td><td>

Recording in Activity Book

Next, Mr P asked the class if digestion was completed in the mouth. “No,” students shared that digestion continued in the “stomach” and “small intestine”. He reminded students of their challenges in fitting the length of small intestine on the SPARKLE apron and the importance of why the small intestine had to be long to facilitate the absorption of digested food. To deepen students’ understanding of food absorption, he showed two hand towels and asked students whether the “Towel A with protruding ridges”, or the “Towel B with flat surface” was able to better absorb water. “(Towel) A”, students responded in chorus. He led students to relate “Towel A with ridges” to the “wall of small intestine”, which allows digested food to be better absorbed.</td><td></td></tr>
<tr><td>Drawing analogy to everyday objects or experiences</td><td>



Using everyday objects as analogies of small intestine</td><td></td></tr>
</table>

Mr P's Class – Modelling and Understanding the Digestive System and Digestion of Food		
Curricular Intent		**Resource Use**
	Consolidate	
Making connections across topics	To conclude the lesson, Mr P revisited the overall function of the human digestive system in breaking down food into simple substances and that students will learn how energy is released from digested food at upper primary.	

Planning and Reflecting Using the Content-Student-Resource Cycle

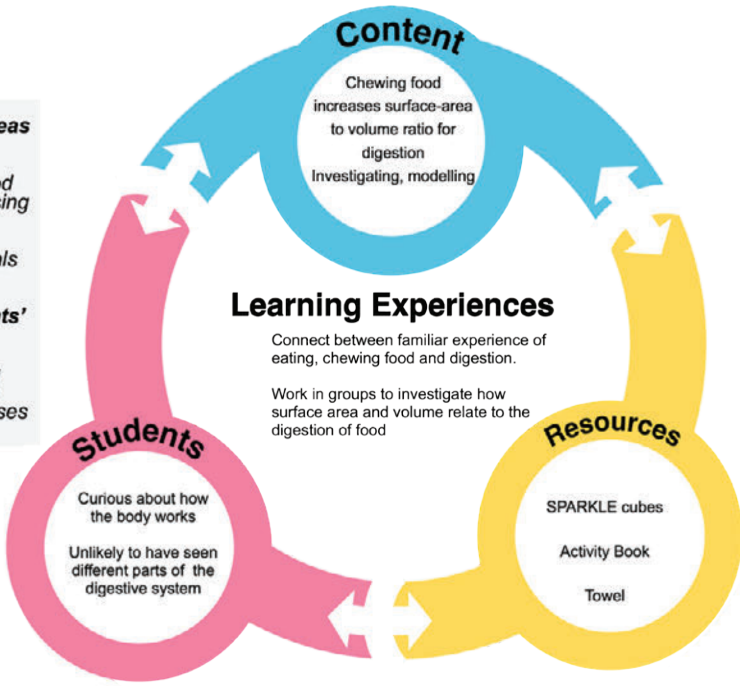
How can I relate students' ideas to scientific concepts?

Relate chewing to breaking food into smaller pieces and increasing surface area

Use familiar household materials such as towel

How do I evaluate my students' conceptual change(s)?

Check students' understanding through whole class and group discussion; and written responses



What strategies can I adopt to engage my students?

Co-construct knowledge with students using Grandma's story

Compare surface area and volume of cubes using hands-on investigation

How can I prepare students to use the science resources?

Use personal story to get students to think why chewing of food is important

Use SPARKLE to appreciate the parts and functions of the digestive system, before investigating the surface area and volume of food

How will students interact with the resources?

Investigate the surface area and volume of food through a guided investigation using SPARKLE cubes

In this lesson, Mr P used a modelling-based teaching and learning approach. Students explored the parts and functions of the human digestive system, in particular how the surface area affects the absorption of digested food at the small intestine.

Mr P first used the SPARKLE apron to engage students in modelling the human digestive system, including the mouth, gullet, stomach, small intestine and large intestine. Such a modelling experience supports students in visualising the parts and relative positions in the human digestive system, appreciating how the various parts come together to break down food into simple substances before being absorbed at the small intestine. After modelling the parts of the human digestive system, the teacher next used the SPARKLE cubes to engage students in comparing the surface area of food before and after breaking into pieces.

The use of modelling in the human digestive system and absorption of digested food adds to the few empirical studies reported on modeling-based teaching and learning of topics such as materials and water cycle in the elementary grades (Acher, Arca, & Sanmartí, 2007; Forbes, Vo, Zangori, & Schwarz, 2015). Such studies are valuable as "Developing and using models" is one of the eight practices of science in which students should be engaged (NRC, 2012, NGSS, 2013).

It is interesting to observe how the teacher's simple customisation of the integrated suite of resources to incorporate everyday conversations (e.g. grandmother's advice on chewing food) and everyday familiar artefacts (e.g. different types of towels) have made the students' investigations more meaningful and deepened their understanding of the concept of food absorption. This highlights the important complementary roles of curricular designers in putting together educational curricular materials, as well as teachers in customising them based on students' needs. Arias et al. (2016) suggests that when designers of educative curriculum materials are purposeful in creating materials, it "may support the creation of rich learning opportunities called for new reforms, allowing for ambitious science teaching and learning."

References

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C7. Is Cactus a Plant?

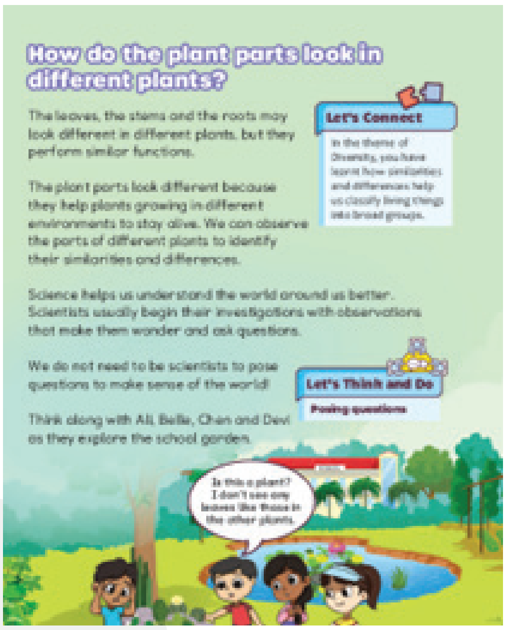
Scientific knowledge are statements of generalisation about specific phenomena. Given that variabilities exist in nature, there are exceptions to generalised scientific knowledge. Exceptions are generally more common in life sciences since groups of living things may be genetically dissimilar and hence display different behaviours or characteristics. For instance, mammals are groups of organisms that give birth to their young alive, have hair, and are warm-blooded. The platypus is a mammal with exception since they have hair, are warm-blooded but they lay eggs. Engagement with generalisations and exceptions in science typically take the form of scientific argumentations, such as with the claims-evidence-reasoning framework (McNeill & Krajcik, 2011). In this chapter, we enter Ms J's classroom where she provided opportunities for students to discuss if a cactus is a plant based on the characteristics of plants that the students have just learnt.

Ms J's Class – Is Cactus a plant? Comparing and Reasoning

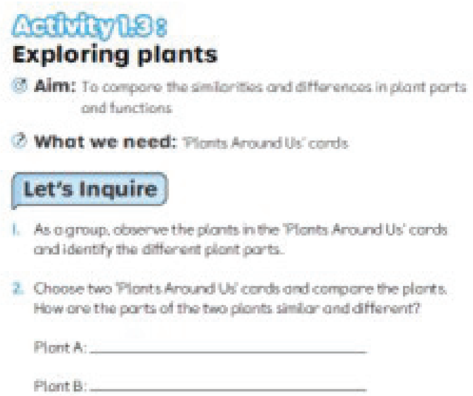
Curricular Intent		Resource Use
	Capture Ms J began her lesson by showing a photograph of a Cactus plant on the slide and asking students what it was. The students responded that it was a cactus. She then asked if a Cactus was a plant. The students replied, "Yes!". Ms. J asked how they knew it was a plant. Student A responded, "It has a stem and leaves". When asked which part was the stem, Student A pointed to the green part, and Student B added, "There are flowers, which makes it a plant".	**Using teacher produced resource to elicit students' knowledge of plants**
	 **Facilitating class discussion if Cactus is a plant**	
	Ms J then asked where a Cactus could be found. She also confirmed with students that a Cactus is indeed a plant and encouraged the class to look for the plant in the school garden.	
Posing questions and demonstrating critical thinking in discussing plant adaptation	She introduced the cactus spikes as needle-like leaves and asked if they looked like normal leaves. The students replied, "No!", noting that they looked different. Ms J explained that these leaves were adapted to their environment. Student C asked why so many needles were needed, and Student D responded, "Animals might damage the plant". Student E mentioned that "sometimes the plant is food for insects".	

<table>
<tr><th colspan="3">Ms J’s Class – Is Cactus a plant? Comparing and Reasoning</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td></td><td>Ms J added that Cactus fruit juice can be found in supermarkets and asked if anyone had seen it. She explained that the Cactus’ stem stores water for long periods. Student F expressed interest in knowing the other purposes of the needles.</td><td></td></tr>
<tr><td>Comparing with other examples of plants</td><td>
Comparing a typical plant with the Cactus

Next, Ms J showed a photograph of a typical plant from an online search and discussed how leaves typically trap sunlight. She highlighted that in Cacti, sunlight is trapped by the stem.</td><td>Using different sources of information -online resource and Textbook to explore plants</td></tr>
<tr><td>Posing questions</td><td>Ms J referred students to their Textbooks. She read aloud from the text, explaining that leaves, stems and roots differ in plants to help them survive in different environments.

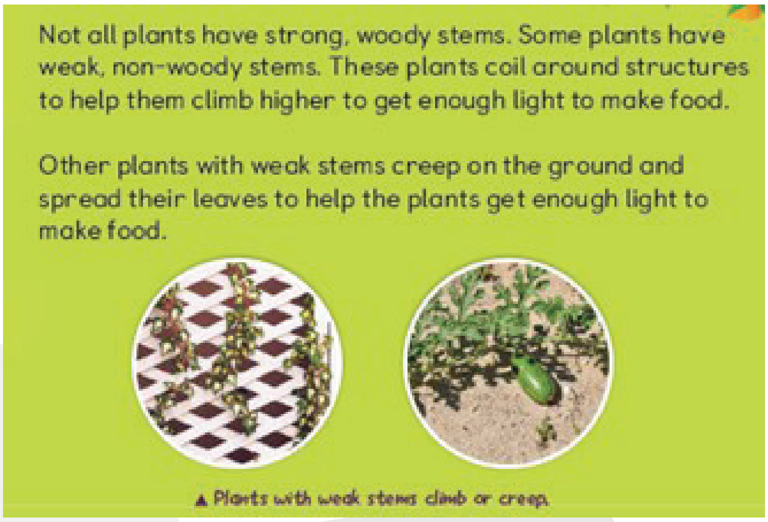

How do the plant parts look in different plants?
The leaves, the stems and the roots may look different in different plants, but they perform similar functions.
The plant parts look different because they help plants growing in different environments to stay alive. We can observe the parts of different plants to identify their similarities and differences.
Let's Connect
In the theme of Diversity, you have learnt how similarities and differences help us classify living things into broad groups.
Science helps us understand the world around us better. Scientists usually begin their investigations with observations that make them wonder and ask questions.
We do not need to be scientists to pose questions to make sense of the world!
Let's Think and Do
Posing questions
Think along with Ali, Belle, Chen and Devi as they explore the school garden.
Is this a plant? I don't see any leaves like those in the other plants.

Using the Textbook as a resource to guide comparison</td><td></td></tr>
</table>

Ms J’s Class – Is Cactus a plant? Comparing and Reasoning		
Curricular Intent		**Resource Use**
Comparing diversity of leaves	Ms J encouraged students to think about different types of leaves, explaining that they can have various shapes, such as oval or round. She then showed a photograph of a purple leaf and asked whether it could still make food. The students answered affirmatively and mentioned seeing leaves in various colours such as pink, white, yellow, orange, and brown. Ms J remarked that blue leaves are rare in Singapore but encouraged students to explore plants in the school garden while reminding them not to damage the plants.  **Leaves** Leaves of different plants can be different in edge, shape, colour and texture. Some have straight edges, while others have jagged edges. ▲ Straight edge ▲ Jagged edge Some are oval, while others are round. ▲ Oval shaped Most leaves are green, but there are also leaves of other colours such as purple and red. Some are waxy, while others are hairy. **Observing and comparing leaves**	
	Construct Ms J handed out Activity Book. She explained that students would be comparing the similarities and differences between plant parts, focusing on their functions.  **Activity 1.3:** **Exploring plants** **Aim:** To compare the similarities and differences in plant parts and functions **What we need:** ‘Plants Around Us’ cards **Let’s Inquire** 1. As a group, observe the plants in the ‘Plants Around Us’ cards and identify the different plant parts. 2. Choose two ‘Plants Around Us’ cards and compare the plants. How are the parts of the two plants similar and different? Plant A: ________ Plant B: ________ **Using the Activity Book as a guide for investigation**	**Using Activity Book to guide investigation**
Observing and comparing plants	Students were given some time to examine various plant cards in groups. Some plants were familiar to the students, while others were new. The cards showed information on the leaves, stems, and roots of the plants. After a while, Ms J asked the students to share their observations of the plant parts.	**Using plant cards from SPARKLE to focus students’ exploration**

<table>
<tr><th colspan="3">Ms J's Class – Is Cactus a plant? Comparing and Reasoning</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td>Connecting to everyday experiences</td><td>Besides examining the plant cards, Ms J facilitated discussion of common plants that students might have come across. For example, she asked whether grass was a flowering or non-flowering plant. She explained that grass was actually a flowering plant, but the flowers are often cut by grasscutters, making them less visible. Students shared other examples such as Aloe Vera, which they had eaten, bougainvillea found along roads, and pandan leaves used for bread. Ms J also asked whether plants such as the Mimosa Plant had a weak or strong stem. A student responded that it needs support.</td><td></td></tr>
<tr><td></td><td>Students were told to explore the two plant cards - Papaya Plant (labelled Plant A) and the Aglaonema Plant (labelled Plant B). The teacher invited them to find similarities and differences between the leaves, stems, and roots of the two plants. The Textbook was displayed on the slide for reference.

Ms J suggested that students could start by discussing the colour or shape of leaves. She asked them which part of their body they used to observe, and the students responded, "Eyes!".</td><td>Using SPARKLE plant cards and Textbook to facilitate comparison</td></tr>
<tr><td>Comparing similarities and differences of plants</td><td>Students also discussed the similarities and differences between stems. Ms J referred to the Textbook and online resources, pointing out that some stems are strong and woody while others are weak.


Not all plants have strong, woody stems. Some plants have weak, non-woody stems. These plants coil around structures to help them climb higher to get enough light to make food.

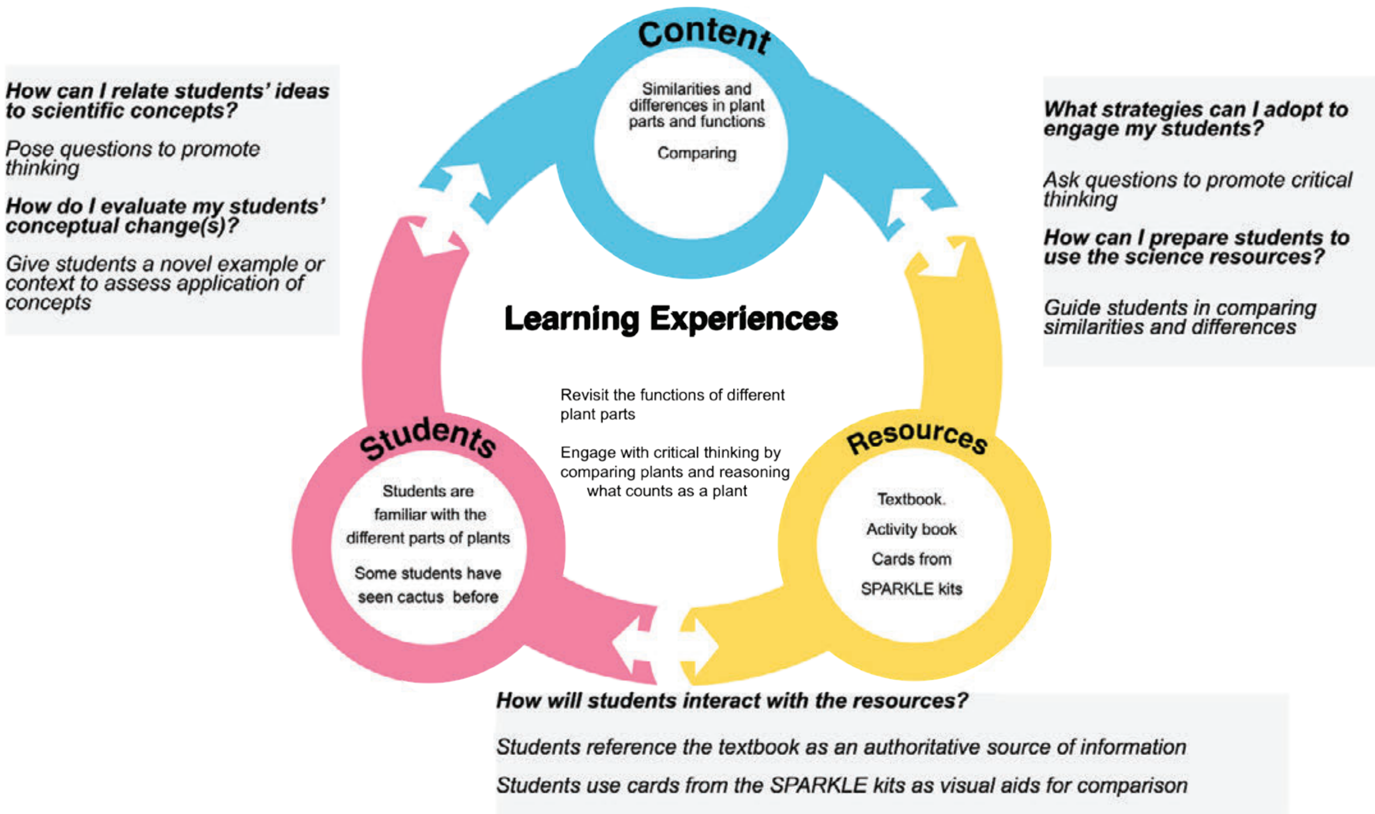
Other plants with weak stems creep on the ground and spread their leaves to help the plants get enough light to make food.

▲ Plants with weak stems climb or creep.

Using Textbook to guide students with concept and vocabulary development</td><td>Using Textbook to guide students with concept and vocabulary development</td></tr>
</table>

Ms J’s Class – Is Cactus a plant? Comparing and Reasoning		
Curricular Intent		**Resource Use**
	Ms J next directed students to compare the similarities and differences in the roots of both plants. The teacher reminded the students to specify which plant they were referring to while comparing. Students recorded their observations and comparisons of leaves, stems and roots in the Activity Book.	**Using Activity Book to record observations**
Posing questions	***Consolidate*** After observing various plants and their parts, students were encouraged to write down questions about the two plant picture cards they had observed. Ms J prompted students to be specific with their questions and provided an example, “Can the pink part of leaves also make food?”	**Using Activity Book to ask questions on plant parts and functions**

Planning and Reflecting Using the Content-Student-Resource Cycle



Ms J presented students with the parts of a common plant and contrasted it with the Cactus, an atypical plant. Students had to apply their knowledge of plant parts to decide if the Cactus was a plant. They had to justify their claims using evidence and reasoning. The introduction of exceptions to general scientific concepts that students learn is pedagogically challenging (Shemwell et al., 2015) and hence Ms J's classroom offered insights into how young students can be supported to engage with scientific argumentation and decision making. Ms J carefully organised and adapted the resources, including SPARKLE cards, online pictures, and Textbook. Each resource was deliberately selected to elicit students' prior knowledge and engage them in observing and comparing different plant parts.

The SPARKLE plant cards, in particular, offered a visual dimension that facilitated students' investigation of plant parts. These cards showed the plant parts such as leaves, stems, and roots, thus enabling students to compare and examine both familiar and unfamiliar plant parts. This allowed students an engaging learning experience which facilitated connections between their observations and prior experiences. Ms J effectively utilised the cards as a teaching resource for promoting collaborative learning and discourse. Furthermore, Ms J's decision to project sections of the Textbook allowed students to verify information as they compared the plant parts.

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McNeill, K. L., & Krajcik, J. S. (2011). *Supporting grade 5-8 students in constructing explanations in science: The claim, evidence, and reasoning framework for talk and writing*. London: Pearson.

Shemwell, J. T., Gwarjanki, K. R., Capps, D. K., Avargil, S., & Meyer, J. L. (2015). Supporting teachers to attend to generalization in science classroom argumentation. *International Journal of Science Education, 37*(4), 599-628. https://doi.org/10.1080/09500693.2014.1000428.

C8. Can Ben See the Minion in a Dark Room?

Light allows us to see fascinating phenomena. Phenomena related to light are closely connected to students' everyday experiences and can be explained using different properties of light. For example, understanding the process of seeing an object involves a combination of various properties of light: A light source gives out light, light travels through space, light reflects when hitting a surface and entering our eyes. Bendall, Goldberg, and Galili (1993) described two naïve conceptions about behaviour of light as: (1) the light from each point of a light source goes out preferentially in one direction rather than in all directions, and (2) light has the tendency to spread out from its source. These naïve conceptions can be changed by intentionally engaging students in inquiry about the phenomena.

To facilitate student understanding of light, it is important to connect the phenomena they observe or investigate with the properties of light inherent in these phenomena. In developing ideas that connect observed phenomena with the properties of light, using visual diagrams can be more effective than relying solely on verbal descriptions. In Mr J's classroom, we learn how to connect what students observe or investigate with what they have already learnt about the properties of light in constructing explanations.

Mr J's Class – Can Ben See the Bright Yellow Minion? Modelling and Communication

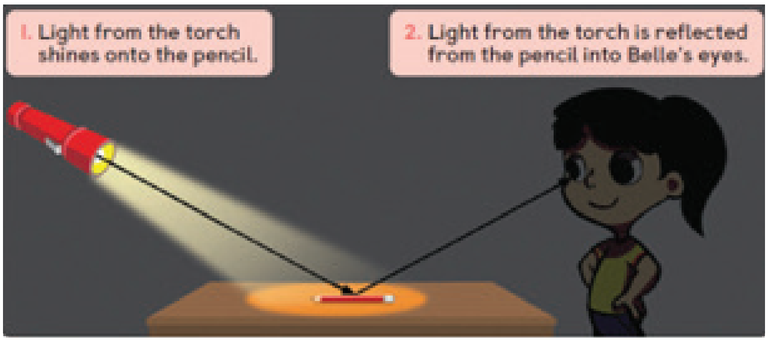
Curricular Intent		**Resource Use**
	Capture	
Recapping prior knowledge on light sources	Mr J discussed in the previous lesson, examples of natural and man-made light sources. He then presented the pictures of light sources (e.g., stars, torch, burning candle, the Sun). Mr J then asked the focus question for the lesson, "How does Ben see the light bulb?". He referred students to the Textbook for examples. He developed students' ideas "How do we see light sources (A picture of Ben)" with follow-up scaffolding questions, including "Why can we see light sources?". While students annotated the relevant concepts in the Textbook to explain how they see light sources. Mr J also annotated "Light enters his eyes directly" in the Textbook through his device.  We can see the light bulb because the light it produces enters our eyes directly.	**Using Textbook to illustrate and explain how light sources are seen** **Using Textbook to show how to represent light entering the eyes**

Mr J's Class – Can Ben See the Bright Yellow Minion? Modelling and Communication

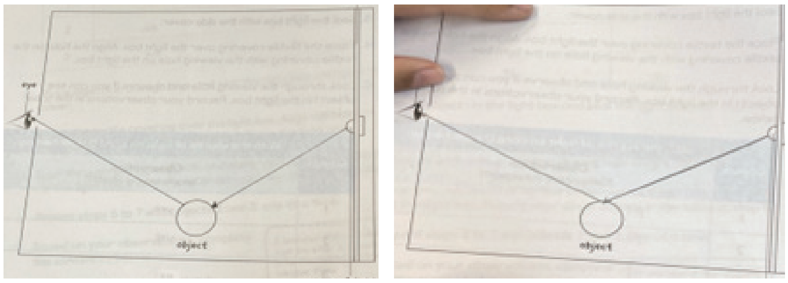
Curricular Intent		Resource Use
Using visual model to explain a phenomenon	***Mr J:*** *This picture shows how it happens. What do you see?* ***Student:*** *An arrow.* ***Mr J:*** *Thank you. It is an arrow. (drawing the arrow with a red mark). This arrow shows us how the light actually travels. It comes from the light source and comes into our eyes.*	
Communicating science ideas	Then, the students were asked to write down their ideas about "How does Ben see the light bulb?" on their personal whiteboards. The students shared their ideas with peers for feedback. Mr J guided students to use words such as "travel" and "enter his eyes directly."  **Communicating ideas using a Whiteboard** Mr J shared one student's answers through iPad. After that, he used diagrams and texts to consolidate the concept of "how light enters the eyes".	**Using whiteboard to share ideas for peer feedback**
	Construct	
Raising a focus question	Using a picture of Ben, and unlit light bulb and a minion, Mr J asked the question, "When the light bulb is switched off, can Ben see the bright yellow minion?".	**Using slides to share a focus question**
Having a discussion based on students' perspectives	When the students provided mixed responses of "Yes" or "No", Mr J then asked students to justify their answers on whether the minion can be seen without light. One student argued that it could not be seen because it lacked its own light. Another suggested that it could be seen due to its bright colour. Mr J asked again, "What about shiny objects? Can these be seen in the dark?".	
	The students again replied with mixed responses on whether a shiny medal, a diamond, a mirror can be seen in the dark. Mr J showed real shiny objects (i.e. glass ball, medal). This discussion elicited what students learnt so far about light sources as well as their alternative conceptions about light sources.	**Presenting tangible objects to elicit prior conception on whether shiny objects can be seen in the dark**

Mr J’s Class – Can Ben See the Bright Yellow Minion? Modelling and Communication

Curricular Intent		Resource Use
	Mr J guided students on how to use the SPARKLE kit to conduct investigation. He demonstrated how to place the three cones (bright yellow, shiny and silver cones) in the box and how to cover the box to have a completely dark environment. The students started to conduct the investigation and recorded their observations in the Activity Book. Most of them observed that they could not see anything when the light was off.	
Conducting investigations and communicating observation	 **Investigating in groups to observe different objects**  **Observing different objects from SPARKLE**	**Using SPARKLE to conduct an investigation**
Communicating observations based on evidence	After the investigation, Mr J revisited the same question, “Can Ben see the Minion?” This time, the students answered “NO” and explained they couldn’t see shiny and bright objects in the dark. Their responses showed a change in conceptions.	

<table>
<tr><th colspan="3">Mr J's Class – Can Ben See the Bright Yellow Minion? Modelling and Communication</th></tr>
<tr><th>Curricular Intent</th><th></th><th>Resource Use</th></tr>
<tr><td></td><td>Mr J asked a series of questions to scaffold students in explaining light sources and how objects are seen. The questions included, "Are the bright/shiny objects light sources? Do they give off light?" "What can we do if we want to see them?" A student suggested, "If we switch on the light, we will be able to see."</td><td>Using Activity Book to record observations of how objects are seen</td></tr>
<tr><td>Conducting investigations based on students' suggestions</td><td>To investigate the student's suggestion, Mr J first demonstrated how to switch on the light source on card D (placed in slot 9 of the light box) before students observed three cones again with the light turned on. The students concluded that the Minion is not a light source and can only be seen if there is a light source.</td><td></td></tr>
<tr><td></td><td>Consolidate</td><td></td></tr>
<tr><td>Constructing explanations</td><td>When consolidating the lesson, Mr J asked students to read the Textbook explanations and diagrams with a guiding question "How do we explain that we can see objects that don't give off light?". He used the Textbook diagram to illustrate how arrows are used to show how light travels.


Using Textbook to model how light rays can be represented
Students then illustrated how they could see the cones in the Activity Book. Some of the student-generated drawings were accurate while others revealed conceptual gaps, e.g. missing arrowheads, double arrowheads, arrowheads in the wrong direction. Mr J highlighted the students whose drawing showed gaps in their knowledge.</td><td>Using Textbook to illustrate how objects can be seen</td></tr>
</table>

Mr J's Class – Can Ben See the Bright Yellow Minion? Modelling and Communication		
Curricular Intent		**Resource Use**
Using and developing visual models to demonstrate how objects can be seen	 Examples of students' drawing	Using student diagrams in Activity Book to assess students' understanding and provide feedback

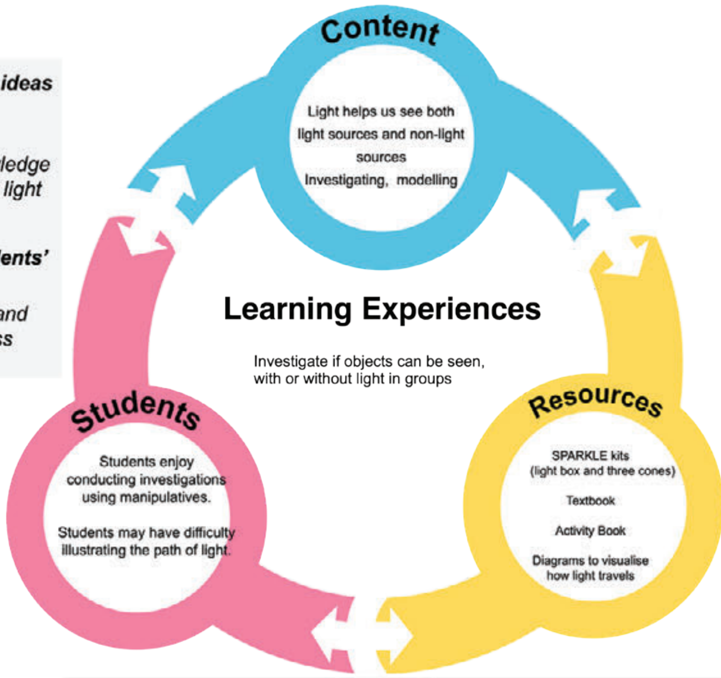
Planning and Reflecting Using the Content-Student-Resource Cycle

How can I relate students' ideas to scientific concepts?

Use a series of questions to activate students' prior knowledge about light sources and how light travels

How do I evaluate my students' conceptual change(s)?

Elicit students' conceptions and use investigations to address alternative conceptions



What strategies can I adopt to engage my students?

Hands-on investigations to observe and explain how an object can be seen

Visual diagrams and student-generated drawing to explain how light travels

How can I prepare students to use the science resources?

Design and explain the focus of hands-on investigations using SPARKLE kits

Guide students in drawing how light travels to explain how an object can be seen

How will students interact with the resources?

Investigate whether objects from SPARKLE can be seen with or without light

Draw light rays to show how an object can be seen in the Activity Book

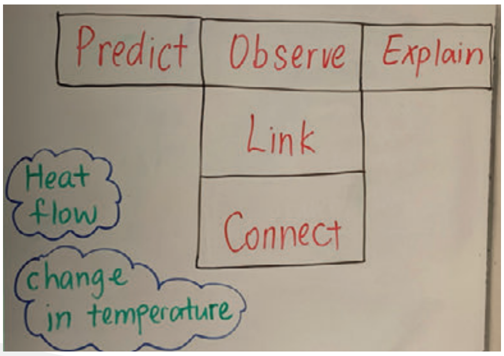
This lesson provides a good example of connecting what students know with what they observe during their investigation using the SPARKLE kit. To explain how the bright yellow Minion can be seen, Mr J used questioning to activate students' prior concepts (e.g., light sources), and scaffold investigations involving three cones (bright yellow, shiny and silver cones) to address students' alternative conceptions (e.g., bright objects are sources of light). Besides, Mr J also intentionally designed interesting connections, for example, making connections between students' favourite character "Minions" and the "yellow cone" used in the investigation. Such connections supported students in exploring how different objects can be seen.

Reference

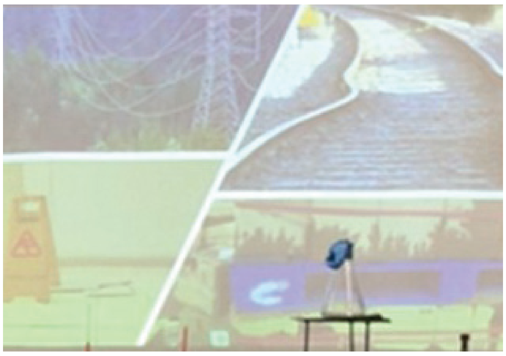
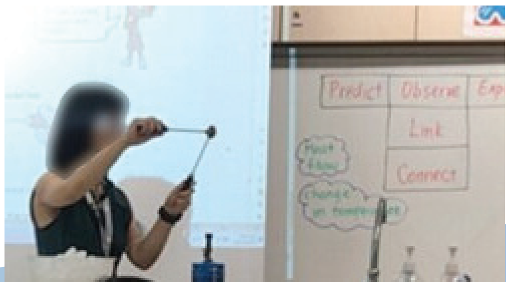
Bendall, S. Goldberg, F., Galili, I. (1993). Prospective elementary teachers' priority knowledge about light. *Journal of Research in Science Teaching, 30*, 1169-1187.

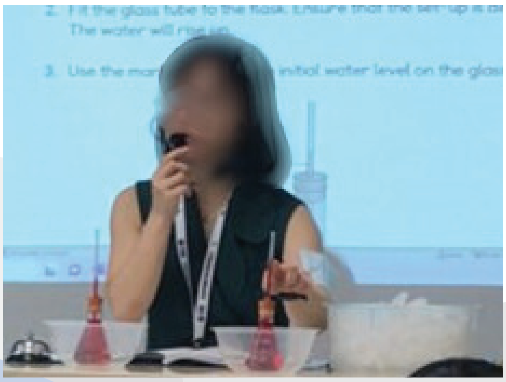
C9. Did the Ring Expand or Did the Ball Contract?

The phenomena caused by heat transfer can be observed indirectly in various ways, such as through colour changes (visually), the sense of touch (tactilely), or the measurement of temperature (numerically). In this way, students are engaged in thinking of heat-related phenomena through observation, hands-on learning and data collection. This story illustrates how demonstrations, coupled with good questioning can effectively support students in understanding heat transfer in solids, liquids and gases, and pique students' curiosity in raising questions. In this chapter, we step into Ms M's classroom to learn: (1) how to facilitate a series of demonstrations to observe, interpret, and understand heat-related phenomena, and (2) how a blend of closed and open-ended questions can be raised and discussed during demonstrations about heat.

Ms M's Class – Expand or Contract – Demonstration, Questioning, Explanation		
Curricular Intent		**Resource Use**
	Capture	
Prepare students on how to observe demonstrations and communicate	Ms M began by reminding students that they would need to make careful observation with their eyes and think with their minds. To guide students' thinking processes during a demonstration, the teacher encouraged them to 'Predict, Observe, Explain' (POE) and 'Observe, Link, Connect' (OLC), which she had written on the whiteboard. She explained that they would first predict what might happen, closely observe the experiment and explain their observations. They would also link their observations with what they have learnt and connect them to everyday examples. This process encourages deeper understanding and critical thinking throughout the experiment.	
	 **Visualising relationship between POE and OLC**	**Using Whiteboard to focus students on predicting, observing and explaining as well as making links and connections**
Recapping prior knowledge about heat	Ms M elicited students' prior knowledge, prompting them with questions like, "What is heat? How do you know when heat is flowing or has been transferred?" The students explained that heat transfer could be observed or measured in various ways; by touch, using a thermometer to measure temperature, using a thermal camera, and checking the change in an object through colour or states of matter.	

Ms M's Class – Expand or Contract – Demonstration, Questioning, Explanation

Curricular Intent		Resource Use
Giving examples of heat gain and loss in everyday life	After that, Ms M engaged the class by relating to familiar experiences, such as barbecuing or roasting marshmallows. She also showed photographs of everyday objects undergoing heat gain and loss, before starting the demonstrations.   **Discussing examples of heat gain and heat loss in everyday life**	**Using slides to discuss examples of heat gain and loss in everyday life**
	Construct	
Raising a focus question **Predicting and having a whole class discussion**	Ms M began the first demonstration by introducing the metal ball and ring. She encouraged students to predict, observe, and explain, as guided by the Activity Book. Throughout the demonstration, the question "Will (or Did) the metal ball pass through the metal ring?" guided the whole-class discussion and students' thinking. Students first predicted whether the metal ball would pass through the ring after being heated, tapping on prior knowledge. Then, students observed the effects of heat on the ball and ring.	**Writing a prediction in Activity Book**
Observing and discussing the effect of heat gain and loss on metal and ball	 **Conducting investigation on solids**	**Using metal ball and ring to conduct the first demonstration**

Ms M's Class – Expand or Contract – Demonstration, Questioning, Explanation		
Curricular Intent		**Resource Use**
	Finally, students explained their observations guided by questioning. The questions encouraged students to connect their observations to prior knowledge about heat transfer (heat gain or heat loss), deepening their understanding of how heat can cause materials to expand or contract. The questions scaffolded students in actively predicting, observing, and explaining what happened and why it happened.	
Constructing explanations	8. Explain your observations. The metal ball ________ . Hence the metal ball ______ pass through the metal ring. 9. Was your prediction correct? Circle your answer. (Yes / No) **Explaining observations in Activity Book**	**Recording explanation of phenomenon in Activity Book**
Observing and discussing the effect of heat gain and loss on red coloured water	In the second demonstration, Ms M used a glass tube filled with red-coloured water to show the effects of heat on liquids. Ms M began by placing the set-up in a container of hot water. As the liquid in the glass tube gained heat, students could observe the red coloured water rising, demonstrating the expansion of the liquid as it gained heat. The rise in the water level visually showed how liquids increased in volume when heated. As the water level reached the top of the glass tube, all the students shouted in unison, 'Overflow! Overflow!' They were thrilled and excitedly yelled, 'YAY!' when the red coloured water overflowed from the glass tube. Next, Ms M cooled the liquid by placing the set-up in a container of ice. The students observed the red water level dropping as the liquid cooled, showing the contraction of the liquid.  **Conducting investigation on liquids**	**Using red coloured water to conduct the second demonstration**

Ms M's Class – Expand or Contract – Demonstration, Questioning, Explanation

Curricular Intent		Resource Use
Discussing student-generated questions and explanation on the epistemic functions of materials	This experiment reinforced the concept of thermal expansion and contraction in liquids, providing an engaging visual demonstration of how heat transfer affected the volume of a liquid. After the demonstration, one student asked, 'Why did we colour the water red in this experiment?' Ms M complimented this student-generated question and engaged the whole class in a brief discussion. Another student explained, 'If the water is the same colour, we cannot see the water level clearly because the colour of the water and glass are very similar.' This shows how the engaging demonstration can foster students' curiosity and inquiring minds, deepening their understanding of the functions of materials in experiments.	
	In the third demonstration, Ms M showed how heat affected the expansion and contraction of gases through an experiment using a balloon. Ms M began by heating the flask with the Bunsen burner, causing the air (or gas) inside the flask to expand.	**Using flask with balloon to conduct the third demonstration**
	As the gas gained heat, it expanded, causing the balloon attached to the flask's neck to inflate. Students observed the effect of heating the flask of gas, as the balloon expanded. After that, the flask was placed in the ice and then the balloon began to deflate as the gas cooled.	
Observing and discussing the effect of heat gain and loss on size of balloon	 **Conducting investigation on gases**	**Record explanation of phenomenon in Activity Book**

Ms M's Class – Expand or Contract – Demonstration, Questioning, Explanation		
Curricular Intent		**Resource Use**
Constructing explanations	Ms M also posed questions to guide students' discussions while conducting the demonstration. Like in the previous demonstrations, the students also recorded their predictions, observations, and explanations in their Activity Books. Following guiding questions, the students predicted, observed and explained the balloon's inflation and deflation using scientific concepts of heat gain and heat loss. The class discussions allowed students to demonstrate their understanding of scientific practices, such as posing questions and constructing explanations, through collaborative knowledge building.	
Providing feedback on students' questions and explanations	***Consolidate*** Ms M concluded the lesson by revisiting the lesson objective. She consolidated students' learning by guiding them to conclude that heat gain or loss can cause matter to expand or contract respectively. She also encouraged students to write down their questions and explanations from the demonstrations in their Activity Books. She planned to review their questions to assess their understanding.	

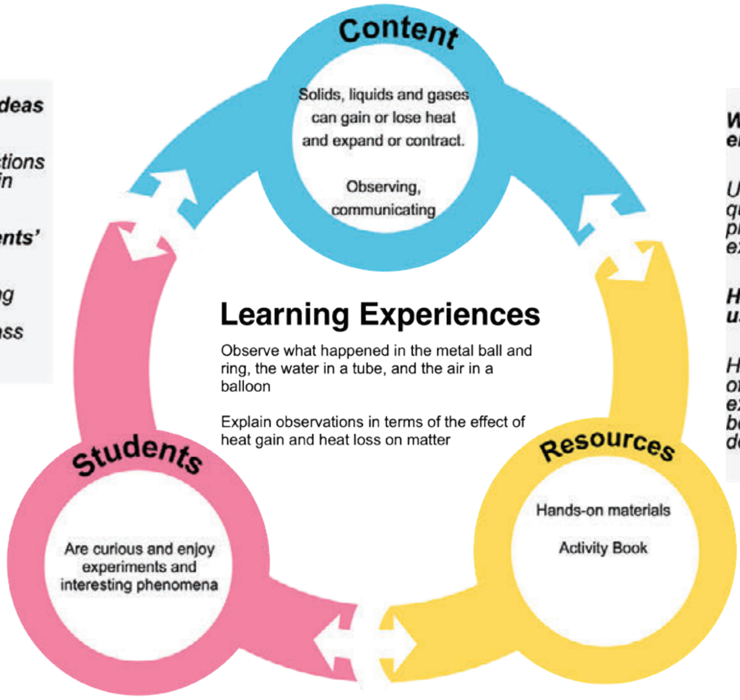
Planning and Reflecting Using the Content-Student-Resource Cycle

How can I relate students' ideas to scientific concepts?

Guide students with key questions to predict, observe and explain changes in matter

How do I evaluate my students' conceptual change(s)?

Check students' understanding through questions and explanations during whole class interactions



What strategies can I adopt to engage my students?

Use demonstration, with questioning to support students in predicting, observing and explaining

How can I prepare students to use the science resources?

Highlight the importance and roles of predicting, observing and explaining based on evidence before the start of the demonstration

How will students interact with the resources?

Students predict, observe, explain and ask question during the demonstrations

Record observations and explanations in Activity Book

This lesson illustrates how a series of demonstrations coupled with good questioning engaged students in understanding and appreciating the effect of heat gain and loss on solids, liquids and gases. During the three demonstrations, students were active inquirers by asking questions. Through these engaging demonstrations, students were guided by key questions to predict, observe, and explain the effects of heat on solids, liquids and gases.

During the demonstration, questions raised by Ms M and students play critical roles in collective sense-making to understand the concept of heat. The demonstration, coupled with questions revealed preconceptions, triggered curiosity, and facilitated whole-class discussions fostering the class's collaborative knowledge building and deeper understanding on science concepts and practices. Research evidence (for example Shon, 2001) suggests that effective demonstration has positive impact on students' conceptual understanding of heat.

Reference

Shon, M. (2001). Demonstrations of lessons: Teaching authentic inquiry in science lessons. *Asia Pacific Education Review, 2*, 35-44.

EPILOGUE

It has been 24 years since the themes of Diversity, Cycles, Systems, Interactions and Energy were introduced in the 2001 Primary Science Syllabus. Over the years, the Primary Science Syllabus has not only strengthened students' appreciation of the connections between the Physical and Life Sciences, but has also emphasised and promoted scientific practices, values, attitudes and ethics among our primary children.

It is inspiring to see our teachers enact well designed opportunities for students to engage in diverse ways of thinking and doing across different topics and contexts. We see students question, conduct investigations, communicate and explain using evidence. We are deeply encouraged by these shifts towards inquiry-based and hands-on learning in our classrooms. We take heart as these pedagogies take root in our teachers' practices.

Syllabus Design and Implementation, a Tight Ecosystem of Partnerships

Syllabus review cycles are part of a continuous process, not a single episode of change. Changes across syllabus cycles built on one another in virtuous loops to develop conceptual understanding, scientific practices, values, attitudes and ethics through the curriculum, as we ride the wave of each cycle towards our goal for all students to appreciate Science for Life and Society.

The game changer in the latest iteration of syllabus review and implementation has been the conceptualisation and development of our integrated suite of resources (Textbook, Activity Book, SPARKLE hands-on manipulatives, Student Learning Space, Teaching and Learning Guide for Teachers) to empower teaching and learning in Science classrooms throughout our schools. This is made possible only by the close partnerships across the Curriculum Planning and Development Division 1 and Academy of Singapore Teachers in the Ministry of Education, the National Institute of Education, and Science Centre Singapore. At the heart of it, it is our teachers who are the stars, as they skilfully translate syllabus and resources into practice.

"To a young learner, Science is not a subject, but a journey of discovery from asking 'why' and 'how'. The Science teacher is responsible for turning this early curiosity and wonder into a lifelong learning adventure, where a question could be the seed for future innovation. Developed through the close partnership between CPDD, AST, NIE and schools, the 3C pedagogical framework and the resources, particularly SPARKLE, empower our teachers in teaching and students in learning of Science, and lead the way towards developing future generations of STEM leaders and advocates."

Ong Kong Hong
Divisional Director
Curriculum Planning and Development Division (2023–current)

Student Centricity and Teacher Agency, Implemention Integrity of Curriculum

With the concerted support of our ecosystem of stakeholders, the Primary Science Syllabus and Resources were designed with an emphasis on student-centricity, focused on students and their learning. Teachers play key roles in customising the resources – making professional decisions on content focus, considering students' needs and progress, as well as selecting the resources to use – often in collaborative dialogue with other science teachers. The range of good classroom practices led to the development of the "Content-Student-Resource" Planning and Reflection Tool, by teachers, for teachers. Such teacher ownership and leadership have enabled the implementation integrity of the curriculum - guided by the aim and learning outcomes of the syllabus while allowing flexibility in curriculum enactment and resource customisation to meet schools' and students' needs.

We are heartened to see teachers skilfully exploring a range of pedagogies to cultivate curiosity, creativity and student agency, aligned with the key outcomes of STEM Education in Singapore, even as students learn science. If anything, these classroom innovations have enhanced academic rigour. In the Trends in International Mathematics and Sciences Study (TIMSS) 2023, Primary 4 students reported enjoying science. They also applied and reasoned scientifically in various contexts, in line with our effort to future-proof learners by developing 21st century competencies such as critical, adaptive and inventive thinking in students.

As a Primary Science Fraternity, Looking to the Future

Syllabus review and implementation span generations of Curriculum and Resource Developers; Master Teachers and Teacher Educators; Science Key Personnels and Teacher Leaders; and Science Education Researchers. All play important and complementary roles in growing our next generation of scientifically literate citizens.

The world today is characterised by change and disruption, accelerated by technological advancements. What promise and possibilities might this hold for the learning of science? How can we prepare our students for such a future?

"The primary science curriculum is a labour of love put together by all who care that our children experience the joy, discovery and wonders of science. It is awe-inspiring to behold that encased in each syllabus is the goodness of all the syllabuses before it. Indeed, our children are nourished by the wisdom of generations who had gone before us when they interact with the curriculum. The current syllabus sets a new bar in offering pupils a heads-on, hearts-on and hands-on experience to engage with Science through the integrated suite of resources. Kudos to our dedicated CPDD, AST, NIE, Science Centre and school colleagues for the tight partnership that made this a reality. You give our primary science pupils the SPARKLE in their eyes!"

Teo Kok Hong
Director, Sciences Branch
Curriculum Planning and Development Division (2024–current)

How do we balance between the timeless and the timely in the learning of science? At the primary level, students flourish through concrete and tactile learning. How can emerging technologies enrich and extend this learning for our younger students? What other ingredients would secure the future for them, as learners and participants of science?

As a Primary Science Fraternity, we have the unique privilege to steer and shape the earliest experiences of our children with science. Let us continue to spark their wonder, curiosity and imagination as we envision the next primary science curriculum, out of our love for the child and our craft.