SEAMEO STEM Planning and Design Learning (PaDL) Framework: Towards 21st Century Skills and Design Thinking

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**SEAMEO STEM Planning and
Design Learning (PaDL) Framework:
Towards 21st Century Skills and Design Thinking**

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FOREWORD

The SEAMEO's motto, "Leading through Learning", affirms the commitment and leadership of the SEAMEO Secretariat to promote quality education, science, and culture in Southeast Asia and beyond. This motto guides the 26 SEAMEO Regional Centres in realising their vision and mission through their various training and research programmes and projects. SEAMEO RECSAM has remained steadfast in playing its role and is still at the forefront in enhancing and advancing science and mathematics education in the SEAMEO region amidst challenging times, notably this COVID-19 pandemic.

This book entitled "SEAMEO STEM Planning and Design Learning (PaDL) Framework: Towards 21st Century Skills and Design Thinking" is another milestone for SEAMEO RECSAM and its collaborating partners – Monash University, Australia and SEAMEO Centres – QITEP in Science, QITEP in Mathematics, STEM-ED and SEN. This is another output of the SEAMEO Basic Education Standards (SEA-BES) project led by RECSAM with funding support from SEAMES under SEAMEO Priority Area #7 "Adopting a 21st Century Curriculum". This publication answers the challenge of what 21st century science and mathematics education should be like through science, technology, engineering, and mathematics (STEM) education and aims to promote and enhance STEM in SEAMEO Member Countries.

Indeed, the importance of STEM has long been widely recognised by governments that it contributes significantly to a nation's wealth, economic competitiveness and social well-being. There are economic articulations of the urgent need for a workforce with STEM skills, and of the transferability of these STEM skills to other non-STEM related careers in society. This STEM PaDL framework is relevant and is a useful resource for curriculum planners, STEM advocates and educators in producing STEM proficient students who are logical thinkers, effective communicators, as well as values-driven and technologically, scientifically, and mathematically literate.

I fervently hope that this SEAMEO STEM PaDL Framework will be used alongside other SEAS-BES publications such as the Common Core Regional Learning Standards (CCRLS) in Mathematics and Science (2017), and Attitudes and Beliefs towards Science and Science Education of Year 9 and 10 Southeast Asian Students (2020).

My sincere appreciation and gratitude go to the Ministers of Education of SEAMEO Member Countries and their science and mathematics curriculum experts, STEM experts from Monash University, Australia, the STEM experts from SEAMEO sister-centres, STEM educators from Malaysian higher education institutions, and science and mathematics teachers from across SEAMEO for their expertise as well as RECSAM management and staff for their hard work and commitment in publishing this book.

Congratulations to SEAMEO RECSAM for another splendid job!

Dr. Ethel Agnes Pascua-Valenzuela
Director, SEAMEO Secretariat Bangkok, Thailand

FOREWORD

In essence, education has the capacity to serve as a fundamental building block for a nation's advancement and development because they share a similar platform in achieving the aim of forming one 'ASEAN Community'. This ASEAN platform has the ability to facilitate the harmonisation of the national education policy frameworks of each SEAMEO Member Country. As a result, the quality of education is raised to greater heights as an outcome of the exchange of information and the incorporation of regional educational values and standards into the curriculum.

RECSAM has initiated various programs and projects in terms of capacity-building and research and development activities as reflected in its 11th Five-Year Development Plan. This project aims to promote STEM Education specifically to enhance the capabilities related to STEM curriculum design development and utilisation of the Common Core Regional Learning Standard (CCRLS) in Mathematics and Science. This learning standard project is aligned under Priority Area #5-Revitalising Teacher Education and #7-Adopting a 21st Century Curriculum of the SEAMEO Education Agenda (2015 – 2035). Hence, a collaboration with the Faculty of Education, Monash University in Australia as project consultant was essential to the success of this undertaking.

The Centre pursued a "Teaching to Transform: 21st Century Skills and Design Thinking in STEM Contexts" regional workshop on SEA-BES Phase 2, participated by eleven Ministries of Education from SEAMEO Member Countries. Outcome of this project relates to the advancement of theoretical understanding of STEM curriculum design from the STEM teachers' cognitive domains. By combining the different educational fields of Science, Mathematics and Technology in a transdisciplinary approach, the research project has the potential to discover new theoretical openings in this area of research. Finally, the SEAMEO STEM Planning and Design Learning (PaDL) Framework aims to improve ASEAN collaboration in the development of high-quality curricular standards and learning assessments that can effectively address ASEAN's changing global context and complexity. The main output of this project is the development of the SEAMEO STEM Planning and Design Learning (PaDL) Framework and accompanying STEM lesson sequence for use in SEAMEO Member Countries.

On behalf of the Centre, I convey my sincere appreciation and gratitude to SEAMEO Secretariat for entrusting this monumental task to SEAMEO RECSAM and financial support. I am hopeful that the SEAMEO STEM Planning and Design Learning (PaDL) Framework: Towards 21st Century Skills and Design Thinking will be successful as a tool for launching a systematic discussion about the future development of a regional integrated curriculum suitable for ASEAN integration with a focus on 21st century skills.

Dr. Shah Jahan bin Assanarkutty
Director, SEAMEO RECSAM Penang, Malaysia

FOREWORD

The genesis of this book came from an invitation. In early 2018, SEAMEO RECSAM invited the Faculty of Education, Monash University, Australia to collaborate on a November 12, 2018 *STEM Colloquium* for Penang state local science, mathematics and technology teachers and academics from Community Colleges, Teacher Education Institutes, and Universities in neighbouring states of Kedah and Perak. A few emails later, we discovered an exciting opportunity was emerging for a larger collaboration on STEM thinking and learning via a four-day workshop. The original Monday afternoon *STEM Colloquium* was offered; however huge demand meant it was presented to almost 180 teachers and educators. Over the next four days, a **STEM community of inquiry** developed at SEAMEO RECSAM in the form of the *Teaching to Transform: 21st Century Skills and Design Thinking in STEM Contexts* regional workshop during November 13 – 16, 2018.

In this Foreword, we explore what constituted this STEM community of inquiry, and why it became so important for STEM education in Southeast Asian countries. The essence of STEM education is **collaboration** and **inquiry**. Our aim was to be collaborative, not just between SEAMEO RECSAM and our team from Monash University, but between all participants at the *STEM Colloquium* and the *Teaching to Transform* workshop. This was critical as collaborating in such a community fuses the personal world of the individual specialist participants from the different Southeast Asian countries - a fusion of thinking and collaborating that built our STEM community of inquiry.

The first collaboration was between SEAMEO RECSAM and the Monash Team, and required us to consider the complexity of our mission: To plan and deliver a workshop to develop STEM Education expertise and a teacher education framework, based on the collaborative participation of approximately 80 people with divergent perspectives, experiences and interests. This collaboration was highly effective thanks to our shared interest (in STEM Education incorporating a thinking emphasis), and an excellent set of standards upon which to base our planning (*SEAMEO Basic Education Standards (SEA-BES) Common Core Regional Learning Standards (CCRLS) in Science and Mathematics*). The second collaboration was between all participants at the *STEM Colloquium* and *Teaching to Transform* workshop respectively, and the logistical and technical support team (please see Acknowledgements for details). We knew a collaborative inquiry with a participant group of this size, and with our incredible diversity was going to be unpredictable, requiring consideration for group dynamics, group communications, personal interests, radically different understandings, and critical discourses in our planning. However, the variety of attributes brought together in this collaborative inquiry became a key driver of **transformative thinking**, and by making the end goals of our collective understandings and differences known, we developed **complementary knowledge** leading ultimately to the success of the program. This emphasis on complementarity is important because without the specialised disciplinary and contextual knowledge across the participants, we would not have been able to develop in-depth understandings of the processes involved in planning for and learning STEM in Southeast Asia.

We are incredibly grateful for the opportunity to collaborate on this book guiding STEM teaching and learning across Southeast Asia. And to the teachers, students and families of Sekolah Kebangsaan Minden Height, Penang for piloting the use of the PaDL Framework, we dedicate this book to you. Your collaboration is deeply appreciated and was essential for our collective learning. The rich discussions that followed the original workshop event (November 13 – 16, 2018), through to the final stages of preparing this book (in early 2022) have helped us learn about the richness of a STEM collaborative inquiry, especially when we explore STEM education by embracing collaboration through a thinking lens, resulting in transdisciplinary learning.

We hope our work can help inspire teachers and students to be curious and hungry for new learning. To be creative and innovative, we must explore the 'making space' between our ears, adopting a STEM Education growth mindset that allows us to ground our problem solving in real-world problems and our learning in the pedagogical research. We have an imperative to inspire others to imagine a better world. We need to build this upon local community and cultural familiarity. We think we have done that in this book. This book is meant to engage educators in Southeast Asia and beyond from a range of backgrounds, education levels and disciplines. It is meant to begin a conversation across disciplines to enhance the awareness of teaching and learning that is necessary for our path to future economic prosperity and environmental sustainability.

We hope you enjoy your journey through this book and we welcome your dialogue and continued conversations that can help to weave this understanding into the rich tapestry of local culture and classrooms.

Assoc. Prof. Dr. Gillian Kidman
(with Dr. Hazel Tan, Roland Gesthuizen and Simone Macdonald)
School of Curriculum, Teaching and Inclusive Education
Faculty of Education, Monash University, Australia

PREFACE

SEAMEO RECSAM has long recognised and taken cognisance of the impact of STEM in the educational systems of the SEAMEO Member Countries. The 10th *Five-Year Development Plan 2015 / 2016 to 2019 / 2020* provides evidence of the variety of projects implemented by the Centre, including training programmes, workshops, conferences and publications. One such recent 2017 publication is the *SEAMEO Basic Education Standards (SEA-BES) Common Core Regional Learning Standards in Science and Mathematics* (CCRLSSM, 2017), which included STEM in its goals and objectives. The book clearly outlines the learning standards and indicators designed to promote and enhance STEM in SEAMEO Member Countries.

The *CCRLS in Science and Mathematics* was used as a reference point in selecting topics and standards when developing the STEM activities and workshop materials for the 2018 *Teaching to Transform: 21st Century Skills and Design Thinking in STEM Contexts, a* week-long regional workshop. This SEA-BES project is aligned with the SEAMEO Agenda Priority #7, "***Adopting a 21st Century Curriculum***", which prescribes the following:

> *To pursue a radical reform through systematic analysis of knowledge, skills, and values needed to effectively respond to changing global contexts, particularly to the ever-increasing complexity of the Southeast Asian economic, socio-cultural and political environment, developing teachers imbued with ideals in building ASEAN Community.*

This priority was realised during the *Teaching to Transform: 21st Century Skills and Design Thinking in STEM Context Regional* workshop. The *STEM Planning and Design Learning (PaDL) Framework* was developed from the systematic analysis of the 14 commonly used Western planning models and the experiences, knowledge, skills, and values of the 80 expert ASEAN educators who attended the workshop. Several principles guided the PaDL Framework construction: focus on the students, not the curriculum; consideration of teacher's vision, focus, objectives, and student needs; availability of the resources in the country; and finally, consideration of the teacher's confidence in developing the tasks.

Following the successful *Teaching to Transform* regional workshop, the PaDL Framework has been implemented in Sekolah Kebangsaan Minden Heights in Penang, Malaysia. Three teachers and 37 students participated in the school tryout (evaluation) of the use of the PaDL Framework. Occurring at the time of lockdown due to the COVID-19 pandemic, the STEM lesson was conducted online. Students and teachers found the STEM activities to be highly engaging and inspiring.

This book features the STEM PaDL Framework with its twin models for teacher planning and student design learning (Chapter 1). It also includes the STEM PaDL Lesson Exemplar used in the school tryout (see Chapter 2) and the STEM Unit Exemplar (see Chapter 3) with the entire learning sequence that teachers can use straight away. Finally, nine theme-focused STEM unit ideas utilising the PaDL Framework are presented (in Chapter 4), with suggested lesson ideas that teachers can further adapt and develop for their students.

We hope that this book and the PaDL Framework can inspire all teachers (STEM and non-STEM) towards design learning and developing the 21st century skills of their students!

The Authors

ACKNOWLEDGEMENT

This book publication was made possible under the leadership of SEAMEO RECSAM in collaboration with Monash University, Australia and SEAMEO sister centres, QITEP in Science, QITEP in Mathematics, STEM-ED, SEN, and the funding support by SEAMEO Secretariat in Bangkok, Thailand. The authors wish to acknowledge and convey their gratitude to the following persons and institutions for their significant roles and contributions in making this project and publication a reality:

- Dr. Ethel Agnes Pascua-Valenzuela and Dr. Gatot Hari Priowirjanto, and Mr. Prasert Tepanart, present and past Directors and Deputy Director for Administration and Communications, respectively of SEAMEO Secretariat for the financial support.
- Dr. Shah Jahan bin Assanarkutty and Dr. Suhaidah Tahir, and Ms. Khor Sim Suan, present and past Directors and Officer-in-Charge, respectively of SEAMEO RECSAM for their leadership, motivation and inspiration in leading this project and in the publication of this book.
- Assoc. Prof. Dr. Gillian Kidman, Dr. Hazel Tan, Mr. Roland Gesthuizen, and Ms. Simone Macdonald for their time and expertise in conducting the workshop, and developing, revising and finalising the STEM PaDL Framework and STEM lessons.
- The 11 Ministers of Education of SEAMEO for the financial support as well as their science and mathematics curriculum specialists for their expertise and insights in the development and finalisation of the PaDL Framework and STEM lessons.
- Workshop participants comprising of the science and mathematics educators and STEM teachers from educational institutions in Malaysia, as well as science and technology enthusiasts and advocates from private organisations from SEAMEO Member Countries for their cooperation and insights in the development of the PaDL framework and STEM lessons.
- Science and mathematics specialists from SEAMEO centres-collaborators (i.e., QITEP in Science, QITEP in Mathematics, STEM-ED, SEN) for their involvement in the development, critique, and finalisation of the STEM PaDL framework.
- Dr. Mariam Othman, Dr. Wan Noor Adzmin Mohd Sabri, Dr. Nelson Cyril, Specialists, staff from Training and Research Division, and Administrative Division.

- School principal, science, mathematics and technology teachers, students and parents of Sekolah Kebangsaan Minden Height, Penang for the school tryout of the STEM lesson adopting the PaDL Framework and responding to the survey.
- Mr. Mohd Faizal Zainoldin, Ms. Jenny Ong, Mr. Michael Loh Min Tze, Mr. Mohd Hanif Amir Hamzah, Mr. Ahmad Fuad Mohd Isa and Ms. Hasdiana Mohd Hassan for their logistical and technological support.
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Development of the STEM Planning and Design Learning (PaDL) Framework

The *STEM Planning and Design Learning (PaDL) Framework* is informed by research. It has been co-designed by the STEM Educators from the Faculty of Education of Monash University, SEAMEO RECSAM Science Specialists, and expert teachers from 10 SEAMEO Member countries for use in Southeast Asian classrooms. We wanted to create a framework that illustrated the complementary roles of planning and design learning processes and provide an easily understood common starting point. The PaDL Framework uses a few words and some simple symbols to show what happens at each stage of STEM design teaching and learning and how each stage affects other decisions and actions. The PaDL Framework is for the use of both the teacher and the student together. This is why the PaDL Framework is unique. Other design thinking models or frameworks facilitate only the teachers' planning or students' designing – we are not aware of a framework that does both.

Inexperienced STEM teachers and learners can follow the PaDL Framework to complete planning and designs in a sequence that optimises learning. We believe the design and simplicity of the PaDL Framework will aid in communicating understanding. Improving the STEM planning, design, implementation and documentation will help ensure that the PaDL Framework will be optimally applied in SEAMEO classrooms. By breaking down the framework into two model processes – one for the teachers' planning, and the second for design learning for student to follow, we envisage innovative lessons delivered by teachers with confidence. The teachers can better gauge the time needed for each task component and guide the learner accordingly. The teachers can also identify the additional expertise they could involve and at what stage to assist with their preparation and delivery, such as using resource speakers or booking equipment.

During the *Teaching to Transform Regional Workshop in November 2018*, each participant benefited from the process of creating the PaDL Framework itself, building step-by-step. Many participants commented on the empowering nature of the task. For example, one group identified their enlightenment stating:

> *STEM is participation, not observation. It is here [indicates a Design component on model]. We are learning from this designing of the frame – like the children will from design of solution (Participant).*

Participants in the regional workshop were organised into ten small groups (see Appendix A for a list of Participants). Each group was supplied with a selection of educational models accessed from the Internet to critique. Five groups were given models aimed at teacher planning (see Table 1.1, page 2), and the remaining five groups were given models related to design learning for students (see Table 1.2, page 5).

Table 1.1
Teacher Planning Models (Appendix A)

<table>
<tr><th>Model</th><th>Source</th></tr>
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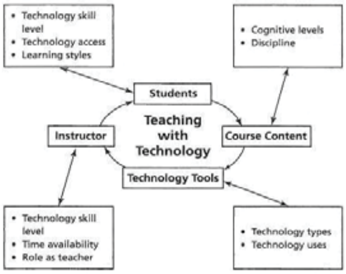

</td><td>Teaching with Technology

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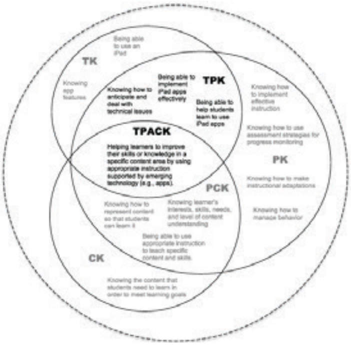

</td><td>A TPACK model depicting the knowledge underlying preservice teachers' decisions while using iPad apps

https://www.citejournal.org/volume-17/issue-1-17/general/tpack-in-special-education-preservice-teacher-decision-making-while-integrating-ipads-into-instruction/</td></tr>
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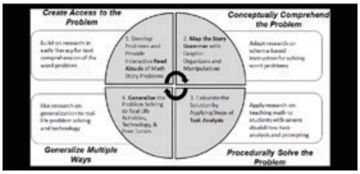
<tr><th>Model</th><th>Source</th></tr>
<tr><td>
</td><td>A conceptual model for teaching arithmetic problem solving to students

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</td><td>Team initiated problem solving Slide 5

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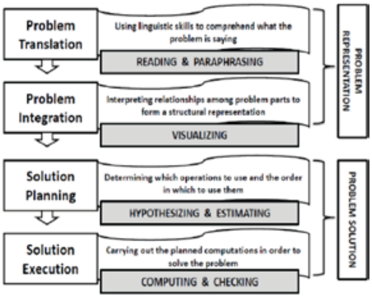
<tr><td>
</td><td>Conceptual framework of the math problem-solving process

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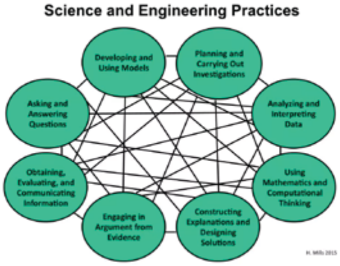
<tr><td>
</td><td>Science and Engineering Practices

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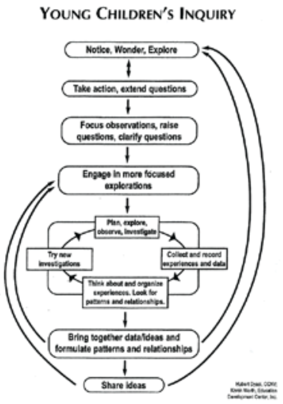
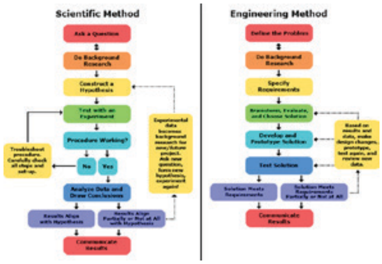
<tr><th>Model</th><th>Source</th></tr>
<tr><td>
</td><td>Science in Early Childhood Classrooms: Content and Process

http://ecrp.illinois.edu/beyond/seed/worth.html</td></tr>
<tr><td>
</td><td>The difference between Science and Engineering

https://imgur.com/gallery/bo1YKNc</td></tr>
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</td><td>Writing Lab Reports: Overview

(https://www.trentu.ca/academicskills/resources/mathsciences_labreportoverview.php</td></tr>
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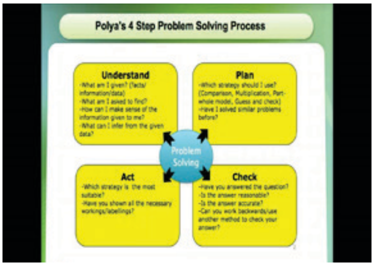
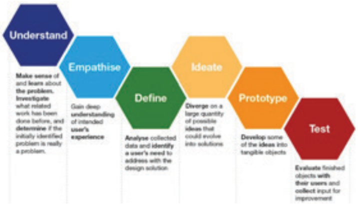
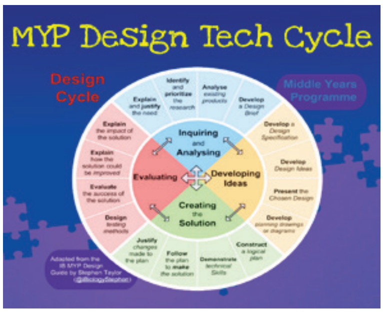
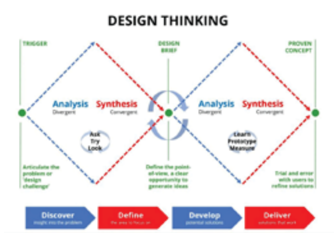
Table 1.2
Design Learning for Students Models (Appendix B)

Model	Source
	Polya's 4 Step problem solving https://www.youtube.com/watch?v=Cbw6-x8DPpQ
	NGSS Engineering Design Process http://workshops.sjcoe.org/Uploads/725201712345744174.pdf
	What is design thinking? https://medium.com/accela-design/design-thinking-it-s-not-just-for-design-411bbd1d42bb

Model	Source
	Design Cycle https://sites.google.com/a/scollege.cl/gr9mypdesigntech/design-cycle
	Getting to grips with Design Thinking https://www.aim.com.au/blog/getting-to-grips-with-design-thinking

Each group was required to spend two hours focusing their critique on the detail *within* each model, looking in-depth at each component, and exploring its merits. After each model had been examined and critiqued in-depth, the groups then considered the broader picture by comparing the benefits *between* the models. Each group spent a further two hours creating their draft *Teacher Planning Model* or *Student Design Learning Model* from these within and between model critiques.

The resultant ten draft models (one from each group) were displayed as posters around the auditorium, and its creators explained each draft model. Using a consensorgram feedback methodology, and small dot stickers, another iteration of the *within* and *between* critique was conducted to identify valuable model components for the PaDL Framework.

A draft Student Design Learning Model with the consensorgram analysis is shown in Figure 1.1. A consensorgram feedback methodology (Marshall & French, 2018) is used to show the considered popularity of each individual concept or relationship included in each of the ten STEM planning or STEM design learning models. Participants used small dot stickers to vote for the inclusion of a concept and/or relationship in the reconstructed STEM PaDL models and framework. Each person places a dot sticker against concepts and / or relationships that they consider to be important, and needed to be included in the new STEM PaDL models and framework.

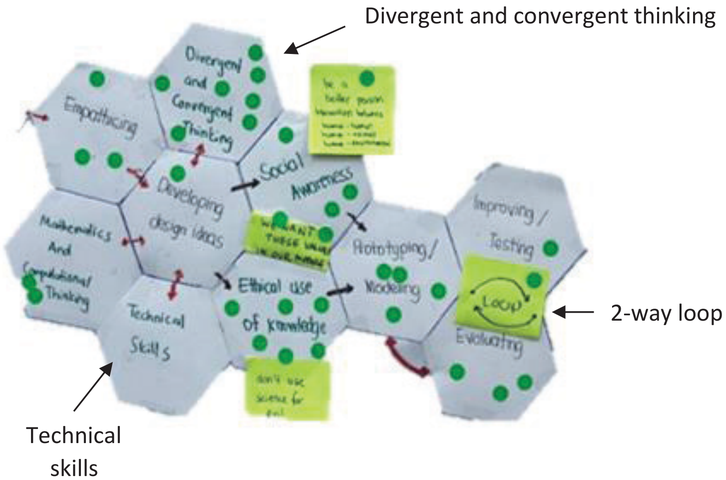


Figure 1.1 Consensorgram feedback methodology on a draft *Student Design Learning Model.*

In Figure 1.1 you can see how the clustering of the dot stickers around a single concept (for example, divergent and convergent thinking) indicates the number of participants (seven in this case) who considered divergent and convergent thinking should be concepts in the STEM PaDL models and framework. Similarly, a 2-way loop relationship between the concepts of improving / testing and evaluating was seen as valuable (five sticker dots). Technical skill development was not considered as being an important concept to include on the Student Design Learning Model. In the discussion, it was agreed that technical skills would be developed throughout the learning experience, so did not need to be specifically located on the model. Each concept and / or relationships was considered during a whole group discussion and a final selection of concepts and relationships was made.

The selected concepts were written on post-it notes and manipulated by the participants over the next day and a half with the assistance of the researchers. Gradually, the two new models emerged, one for the teachers' planning, and the second for the students' design learning. Following the same *within* and *between* critique methods as used to initially critique the 'Western' STEM pedagogy models, the concepts and relationships were synthesised into - the *STEM Planning and Design Learning* (STEM PaDL) *Framework*. The STEM PaDL Framework consists of two models – one for Teacher Lesson Planning and one for Student Design Learning. The remainder of this chapter will explore these two models.

Teachers Planning Model **+** **Students Design Learning Model** **=** **STEM Planning and Design Learning (PaDL) Framework**

The STEM PaDL Framework illustrates the complementary roles of the *P*lanning *a*nd *D*esign *L*earning processes, and provides a common starting point for teachers and students.

1.1 Teachers Planning Model

Figure 1.2 shows the Teacher's Planning Model and has a starting point of ***Creating Enthusiasm***.

1.1.2 Let's Go! Create enthusiasm with your class

It is important you begin the students with great enthusiasm. You and the students are going on a learning journey. The start of the class needs to celebrate what is about to come. For many classrooms, it also marks a point when there is a change in the way that teaching and learning has been done. In addition, it is an opportunity for you, the teacher, to connect with your students and to explore their cultural backgrounds, local context and preferred learning styles. If you show excitement and intrigue, it will enhance the students' wonder and desire to engage.

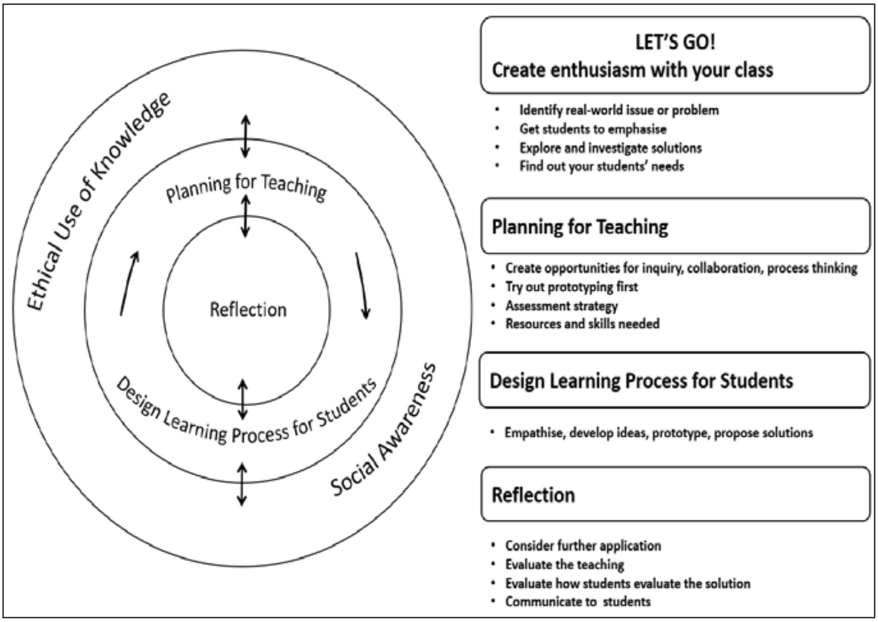


Figure 1.2 Teachers Planning Model.

Why create enthusiasm?

Careful planning of the introduction and launch of your STEM problem solving project, and associated inquiry-based learning will enable your students to better understand the goals of the activities, justify the cultural connections, and enable them to deeply connect with the project mission. If this is not done correctly, student understanding and project ownership will be reduced along with engagement and ongoing interest. This will undermine opportunities for deep thinking and creativity. A great STEM project demands an inspiring educator.

How to create enthusiasm?

You need to explain to students that you are challenging them in new and unfamiliar ways. Students are not to rely on explicit clues, rote memory or hidden answers. Instead, you provide scaffolding and opportunities to help them make sense of where the project will go and what they need to learn. Instil a sense of purpose, build passion and drive. Find how to arouse interest and engage your students. Prepare your students to embrace frustration, mistakes and blunders. Be open to questions from your students.

1.1.3 Ethical and Social Awareness

Your class is enthusiastic! The students are excited to learn and to meet the challenge. However, you will need to help your students contain their excitement and to work together, respecting each other, and the research process.

In this step, you need to consider how to inform students of the moral decisions they will make as they collect and use evidence, and the problems of falsification of data. It is necessary to be sceptical, but essential to be open to alternative explanations. You need to help your students to consider, and respond to, the ethical and social norms of behaviour as they work in small groups and share learning ideas.

Why have ethical and social awareness?

If your students have a social awareness, they can empathise with the ideas of others, and engage in positive classroom behaviours. Thus, a classroom is created with a focus on learning. Students with strong social awareness are able to communicate with their peers and resolve conflicts when they arise.

How to behave ethically and with social awareness?

Ethical behaviour involves demonstrating respect for moral principles that include honesty, fairness, equality, dignity, and diversity.

Students need to carefully consider what their peers want, and then plan to communicate with them in a way that is intended to meet everyone's needs. This is being socially aware. Being socially aware is a natural response to people, taking their situation and needs into account as much as possible.

After exploring the ethical and social learnings you want to develop in your students, begin thinking of the content you can teach to develop students' ethical and social awareness. How will you develop these skills in a technology enhanced mathematics and science focused activity?

1.1.4 Planning for Teaching to include the STEM Design Learning Model for Students

In this step, you incorporate your ideas about creating enthusiasm, a real-world problem or issue for students, and prepare a scenario challenge. Connect your scenario challenge to your curriculum, and plan the sequence of learning activities, scaffolding ideas, resources, and assessment. The sequence of learning activities will lead students through the STEM Design Learning process (empathising, developing design ideas, prototyping / modelling, proposing solution). As you plan, ensure you explicitly include the following questions in the lesson plan:

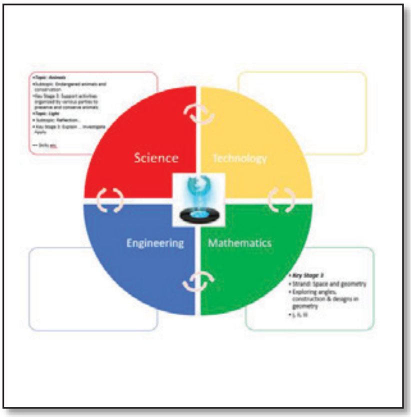
- How would you enable your students to consider the ethical use of knowledge, implications and consequences of their solutions?
- How would you enable your students to consider how they will work cooperatively in groups, and how to conduct their inquiry and develop other 21^{st} Century Skills?

It is important these skills are developed in addition to the content knowledge we normally teach and assess.

1.1.4.1 Why students use the STEM Design Learning Model?

The STEM Design Learning Model is a pedagogical approach to develop students' collaboration, problem solving, and 21^{st} Century skills, while learning and applying their disciplinary knowledge and skills. These skills are not innate, they need to be developed through enriched classroom learning opportunities. If you plan for such learning, we expect your students to strengthen their creative abilities. They will be able to develop a creative confidence and also inspire others, take risks, and to develop resilience. The STEM Design Learning Model is described in greater detail in Figure 1.2 (page 9) of this chapter. However, we must emphasise that you must incorporate its use into your planning for optimal teaching and learning.

1.1.4.2 How to plan for teaching?



Use the Unit plan template (see examples in Chapters 3, 4 and 5) to plan a series of lessons or a unit of work around a scenario and issue. Plan with other subject teachers teaching the same class. Incorporate the *Common Core Regional Learning Standards (CCRLS) in Science and Mathematics* or curriculum from other subjects.

Have fun trying out the prototyping and other activities first before you teach the lessons. Incorporate activity ideas from the examples in this book. By trying out the prototyping first, you will experience the students' learning, and have a greater empathy and understanding of the learning experiences.

Reflection is critical. After each lesson, reflect on the strengths and areas for improvement of the activities, resources, instructions, scaffolding, and assessment. Also reflect on your own planning process, and the students' design learning process.

1.1.5 Reflection

Throughout all stages of planning, you must consider your overall goal to ensure you meet the *Common Core Regional Learning Standards* or your country's national curriculum. Questions you can ask yourself during the planning are: Are the students productively engaged and how do I know if they are? What additional assistance, support, and / or resources will further enhance this lesson? What can I do differently, and why do I need to have options?

In your planning, consider what you are doing in your classroom, and what you imagine the students are doing in the lesson. Think about why you will be doing this. Then, think about whether you think this will work for your students and for yourself.

Why reflect?

When you explore your own planning and teaching through reflection, you experience changes in your attitudes and awareness. This benefits your professional growth as a teacher, as well as improvements to the learning support you provide to your students. By reflecting, you begin to exercise control and open up the possibility of transforming your everyday classroom life.

How to reflect?

When reflecting, you can consider the next two questions: (1) How can I help my students to learn, create, connect, and communicate ideas and concepts better? (2) How will this help my students learn and reflect on their own learning?

You need to move beyond such "how to" questions like those just asked, and start asking "what" and "why" questions. Asking "what and why" questions give you power over your teaching. More powerful questions would be: (1) What can I do with my pedagogies to help my students to learn, create, connect, and communicate ideas and concepts better? (2) Why will this help my students learn and reflect on their own learning?

Reflection is not a single step added to the planning. It is an iterative cycle we all need to follow as shown in Figure 1.3:

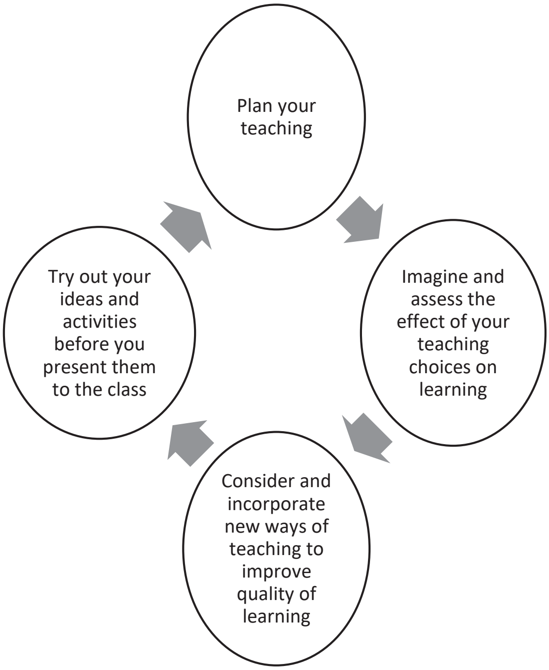


Figure 1.3 The iterative cycle of reflection in the STEM PaDL framework.

We need to repeat the process again and again: your self-reflection should never stop.

1.1.6 Iteration and making the process your own

The Teachers STEM Planning Model is iterative and requires multiple cycles. In your STEM planning, you will need to go back to the previous step or even back to the first step, in order to go forward. This process is only a suggestion and, in the end, you have to make the process your own and adapt it to your style and your work and to the cultural conditions of your classroom. It is about your way of thinking and working with your students.

Creating Bionic Hands and Holograms

1.2 Students STEM Design Learning Model

This section will explain the STEM Design Learning model and process for your students. The model is shown in Figure 1.4 below. There are four design stages that students will work through including (i) empathising, (ii) developing design ideas, (iii) prototyping or modelling, and (iv) proposing a solution. Notice that this isn't about revealing a solution or discovering a solution. Your students should not be encouraged to "guess the correct answer" then create the "correct solution". It is about designing something from their imagination then talking through their ideas.

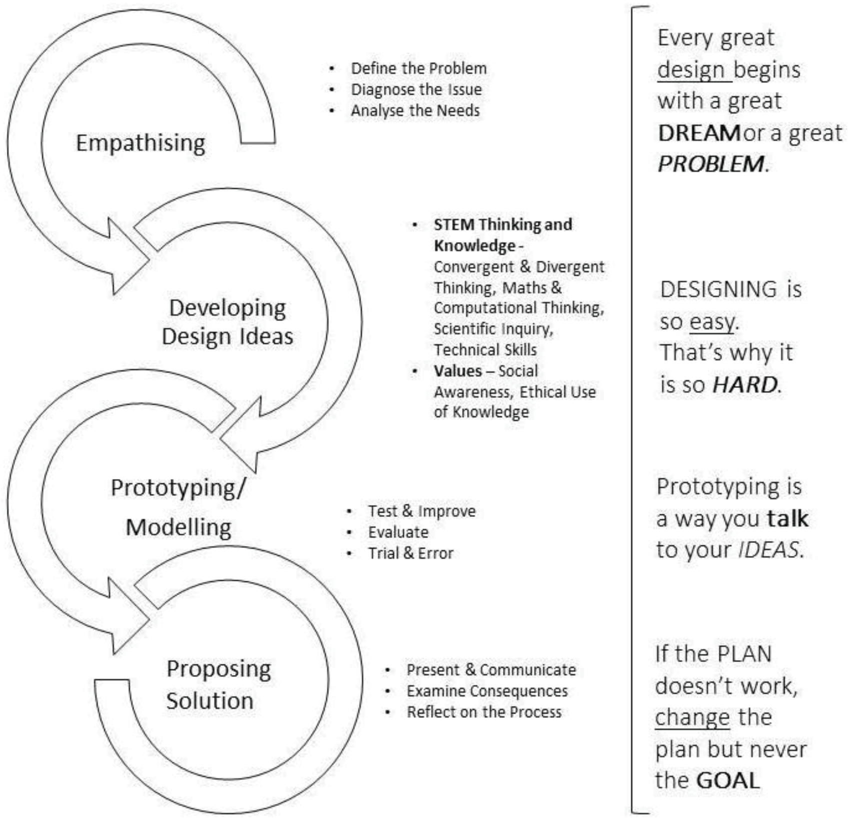


Figure 1.4 Students' STEM Design Learning Model.

1.3 What is Empathising?

The empathy stage of the student design learning model is about the teacher helping the students to develop a human-centred view of problem solving. You can have students observe other people, examine their context and listen to their needs and requirements. This will help your students to have a deeper sense of empathy and understanding. A great project demands a rich empathy experience.

> ***"Empathy is seeing with the eyes of another, listening with the ears of another and feeling with the heart of another."***
> ***– Alfred Adler***

1.3.1 Why include empathy?

The empathy stage puts other people at the start and heart of any planning activity or research project. This human-centred approach ensures that the design and proposed solution is anchored in the real-world. It will help the students to make the right decisions and avoid design failure when solving problems.

1.3.2 How to empathise?

You and your students should not guess what other people need without first listening to the other people. A lack of empathy will contribute to design failure. Without empathy, there is no solution. There are many different tools and techniques for this stage; from interviewing to empathy maps. They all require listening and observing people. To do this, you and your students will need to challenge yourself, examine any biases and learn to ask better questions. *Explore the heart not just the head*. You can help your students to cultivate a sense of curiosity, and help get you out of your usual comfort zone.

Only when you and the students have combined all the collected insights can the students begin to synthesise them into an outline and define the problem. This ensures that the prototype or model puts people into the centre of the solution, and does not contribute to an undesirable outcome.

1.4 What is Developing Design Ideas?

In this stage, you need to have your students brainstorm many different ideas, based on the problem, issue and needs found in the empathy stage. Encourage the students to go wild with different ideas! Write or draw them out. Link different things together to create new ideas. Ideas will push your students to the next step of prototyping and modelling. Your students should develop and use a sense of social awareness for an ethical use of knowledge.

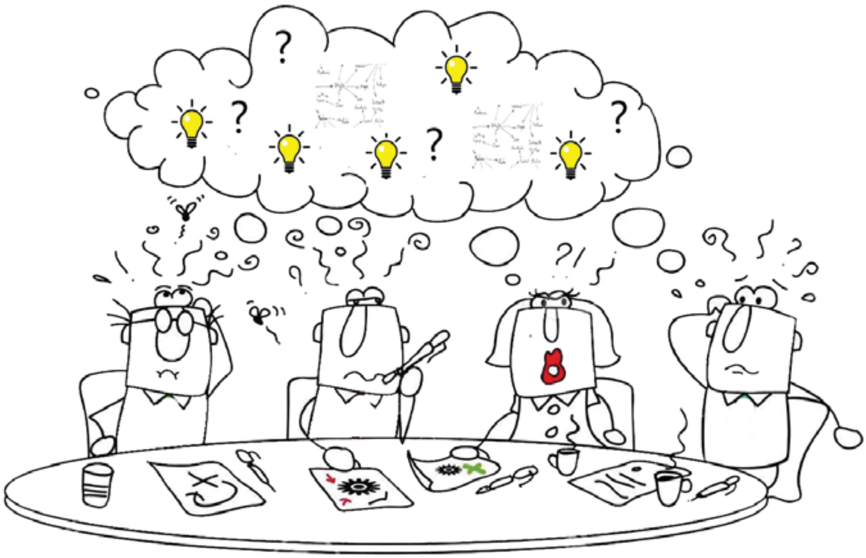
1.4.1 Why develop design ideas?

You need to encourage your students to think creatively and to generate the widest possible range of ideas from which they can choose their best design (this is called **divergent thinking**). Students select their best design options to generate their solution for the build. Through testing their prototypes or models they will use **convergent thinking**.

1.4.2 How to develop design ideas?

It is necessary for you to remind your students to combine their knowledge and understandings from different subjects (Mathematics, Science, Technology) to create new thinking about how to ***generate a solution*** to a problem or issue. Notice that we advocate ***generate a solution*** and not 'find the answer'. Finding the answer implies there is a correct and or incorrect response. This is not the case in STEM. There are many responses to all problems and solutions, some better than others. We recommend you acknowledge the idea of many responses, and adopt the idea of having your students generate a solution – one solution from many.

Encourage your students to use logical thinking, computational thinking, and their imagination. Building things (prototyping) can be a way to help your students come up with new ideas. Use a Brainstorm, Mind Map, or Role-Play, then ***Draw a Sketch***.



(Modified from Clipart Drawing gg66558954)

1.4.3 Why and how to draw a sketch?

You might find that your students develop a design idea (previous section) and also draw sketch steps at the same time. Some students like to use a diagram to explain their thinking. When this happens, the student describes the ideas both verbally and in a drawing. This is an ***excellent approach to design thinking***.

Figure 1.5 shows a sketch that was drawn in two stages. The first diagram is the small square based pyramid (identified as 'A'). The student was describing what he saw as the final product, or a solution to the problem. Here the idea was a 3-dimensional object. When a peer enquired about how such a prototype could be constructed, the student explained through a net diagram (identified as 'B'). The explanation was that the pyramid could be imagined as flat, then cut out and folded to be a 3-dimensional prototype. This combination of a flat-sketch (2-dimensional) to 3-dimensional is ***sophisticated dimensional thinking***.

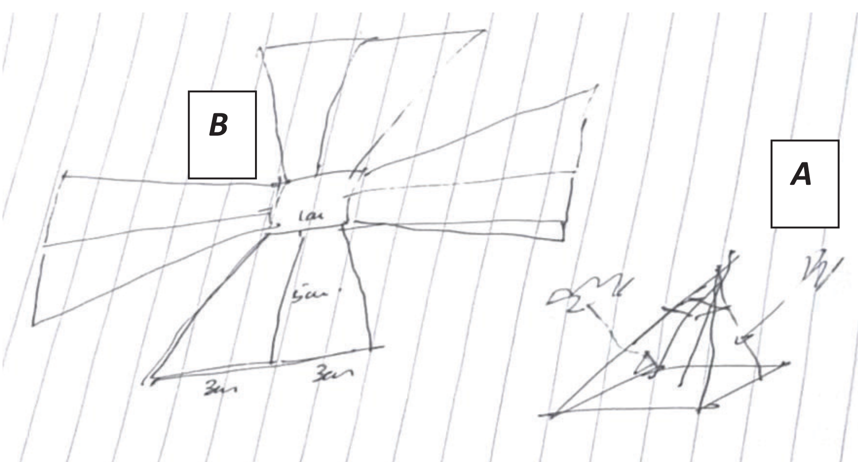


Figure 1.5 2-dimensional and 3-dimensional thinking communicated via sketches.

Figure 1.6 shows sketching solutions to a problem from a team of students. The five sketches are interesting visualisations of the same problem. Sketch 'A' is composed of four discrete elements, Sketch 'B' depicts a process of six elements, and Sketches 'C' both depict web-like arrangement of elements. All sketches are valid ideas for a solution. The team will decide if the best solution is as isolated elements (A), a process (B) or a web (C), or a combination of these.

The students need to be encouraged to carefully choose which ideas to prototype (choose e.g., most logical, most liked by people, most unexpected). Use these different ideas rather than just one idea everyone agrees with. The best solution will ***incorporate ideas from each sketch.***

Figure 1.6 Multiple sketches of the same problem.

When you are introducing your students to the Draw a Sketch step, please inform them of the characteristics you value in a sketch. We have included a short list to get you started below, however we suggest that you add to the list with additional characteristics that you feel are relevant to your particular scenario. Not all characteristics need to be used for assessment purposes each time – some will not be relevant.

Characteristics as criteria for Sketches

- Life-likeness of the object in the sketch
- Detail and diversity of elements in the sketch
- Word or numerical labels and explanations
- Object and should include an end-function in mind
- Object that has a real-life value
- Typically created by a team of designers
- Contain sufficient information to enable construction

1.5 What is Prototyping and Modelling?

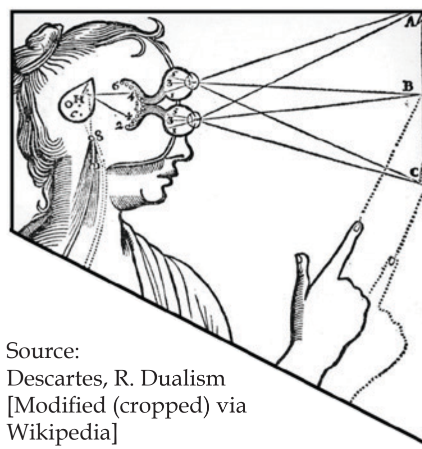
This is the favourite stage of the design learning. The modelling stage of the student design process is about the construction of a unique model that solves a real-world problem. The final prototype or model is a representation of a proposed solution – but ***it does not need to be functional***.

It should clearly illustrate what the solution ***could look like***, how it works or how it ***could be used***. A model does not need to be the same size or even made of the same materials as the proposed solution. The final prototype or model your students design and build is a display of their imagination, creativity and playful tinkering.

There are many different tools and techniques for the draw-a-sketch stage; from ideation and testing to hands-on construction. They all require the student to:

- plan using their mind;
- look with their eyes;
- build with their hands; and
- listen to everybody else's ideas and questions.

Student thinking is made visible through the sketch process.



Source:
Descartes, R. Dualism
[Modified (cropped) via Wikipedia]

Sketching the ideas is critical to STEM Design Learning.-

1.5.1 Why build a prototype model?

A great project demands a curious mindset. This enables a compelling modelling experience and an interesting prototype or final model to be designed, built then shared with others. You need to encourage your students to generate and build ideas from their imagination and personal experiences. The prototypes can represent the behaviour of a solution, or test the solution in different ways. It is something that your class can showcase and learn about. The modelling process rapidly moves from an initial paper design towards a working solution, a physical 3-dimensional model or prototype, with idea checking along the way.

1.5.2 How to create new knowledge?

The creation of new knowledge involves the construction of ideas and models. To do a construction successfully, the students will need to use the inquiry learning approach, and they must embrace failure and learn from their mistakes. It is important that you allow your students the chance to fail – so that they can learn from it.

Moving from idea generation to hands-on action, and then onto construction requires mental activity that constructs new knowledge and objects. To do this, your students must collaborate in groups and draw sketches and plans, communicate with others to explore alternative ideas, and build new knowledge.

You can help your students by supplying model construction kits, cultural contexts and by cultivating a sense of playful tinkering and innovation with strategic questioning to promote deep thinking. Your students must work as a group, find the courage to explore with their hands and with their friends. Design thinking is not a task from memory, and certainly not from a textbook.

1.6 What is Proposing a Solution?

In this stage, you and other students provide feedback to a design team. Allow students to conduct their own evaluation of their prototype or model, then consider the consequences, and come up with their final solution to solve the problem. This is then shared with the whole class who also provides an evaluation.

Students will need time to finalise their prototype or model so that it is as realistic and as good as possible given the time frame and resources. Students can also decide how to present their solution to the class audience. The aim of the presentation is to convince the audience that their solution is the best possible. This is often called a 'pitch' (see figure 1.7) – where the design team has to 'sell' their prototype. A jingle, an advertisement campaign, or a comedy skit to attract attention are possibilities – but let your students decide on how they will do their 'pitch'.

Figure 1.7 The 'Pitch'.

(Modified from: https://limeproxies.netlify.app/blog/the-best-sales-pitch-isnt-a-pitch-at-all/)

1.6.1 Why propose a solution?

The student pitch can help connect the prototype back to the context or problem, and check if it is a good solution. It can help communicate the prototype to other stakeholders. It can assist with your reflection on the entire design process and make improvements.

1.6.2 How to propose a solution?

The questions below would guide students in considering their solutions. In responding to these questions, your students are evaluating their work, and considering others as they contemplate the communication aspects of their pitch.

1. Does your prototype solve the problem?
2. What are the consequences of the model when it is used?
3. How can you use words, diagrams, graphs and other media to present your solution to convince others?

Chapter 2

Evaluation of the STEM Planning and Design Learning (PaDL) Framework

As outlined in Chapter 1, the STEM PaDL Framework consists of two model processes – the design planning for teachers and the design learning process for students. This framework is intended for use by both the teachers and the students for optimum learning.

In the Design Planning model, teachers work through the 4 stages: (1) create enthusiasm with the class, (2) planning for teaching, (3) facilitating the design learning process for students, and (4) guiding the reflection. In the Design Learning model, the students also undergo through the 4 stages: (1) empathising, (2) developing design ideas, (3) prototyping / modelling, and (4) proposing solution. This Design Learning model is designed to enhance STEM thinking and knowledge generation which includes creative and critical thinking, mathematics and computational thinking, scientific inquiry and technical skills as well as values relating to social awareness and ethical use of knowledge, in addition to the engineering skills needed to bring an idea from sketch or drawing to prototype or model construction.

As summary of the STEM Lesson for trialling, in the "empathise" stage, students engaged directly with their peers to understand the harmful effects of indiscriminate disposal of used faced masks as presented through a problem scenario and the need to develop a tool for face mask collection in a STEM design activity. In the "developing design ideas" and "prototyping / modelling" stage", students work in teams to brainstorm solutions and to use feedback to iterate on their designs. In the "proposing solution" stage, students then present a design matrix, describe their designs and materials used, problems encountered in creating their prototypes / models and their strategies used in overcoming the challenges.

An evaluation of the PaDL framework through trialling was necessary to improve both models – the Design Planning for Teachers and Design Learning for Students. This chapter provides a description of the PaDL Framework trial or evaluation.

2.1 Training of Trainers Workshops (RECSAM and School Teachers)

For the purpose of trialling and evaluating the STEM Planning and Design Learning (PaDL) Framework, two *Training of Trainers* (TOT) workshops were conducted. The first workshop was conducted on 6 and 8 April 2021 involving eight RECSAM Science Education Specialists while the second workshop was conducted on 20 & 21 April 2021 with two mathematics and design subject teachers from Sekolah Kebangsaan Minden Heights, Penang together with a RECSAM Science Education Specialist.

The first day started with the introduction of the STEM Planning and Design Learning (PaDL) Framework wherein each participant was given a copy of the PaDL Framework and a copy of a COVID-19 problem scenario (see Figure 2.1).

City Council

Waste Management Crisis

We need your help

Contaminated face masks are littering our streets and Penang Strait. We need you to design, and then create a model of a tool to collect contaminated masks for disposal.

Everyone needs to be more responsible with the disposal of their masks

Figure 2.1 COVID-19 problem scenario.

The participants initially explored the Design Planning Model for Teachers. Discussions were conducted to understand the essence of the Design Planning Model followed by a discussion on curriculum alignment between the PaDL Framework and Malaysian vision which highlights cross-curricular elements. All participants were given a reflection form via a Qualtrics file for the provision of comments and suggestions relating to the Design Planning Model. Following this, the participants explored the second component of the PaDL Framework, the Student Design Learning Model. The participants again discussed the big ideas underlying the model and its link with the Teachers' Design Planning Model. Participants were given a second Qualtrics reflection form to provide comments and suggestions relating to the Student Design Learning Model.

After gaining understanding of the two models, participants were divided into groups of three for a team Design challenge. This challenge was for the participants to apply their understanding of the PaDL Framework and how it could be used for effective teaching and learning. Each design team was provided with toolkits filled with a variety of materials that are easily obtained from home (e.g. satay sticks, spoons, drinking straws, stationery, light cardboard, etc.). The participants were given a checklist to check the materials in the toolkit aimed at familiarising them with the available materials.

Each team was tasked to come up with a sketch or drawing of a tool that could collect a contaminated mask for proper disposal. Team members were encouraged to make multiple sketches of tools within 30 minutes. The participants showed enthusiasm and dedication while doing the task of sketch designing. Each team was directed to choose the best sketch design to build a model or prototype using the toolkit. A time of 1 hour and 30 minutes was allocated to the build.

As a concluding activity, each team presented their prototype or model of the face mask collector. The participants shared their experiences including descriptions and reasons behind their models or prototypes, challenges encountered and how they overcome them. Generally, the two Training of Trainers (ToT) workshops were a success as the participants were able to gain understanding of the two models and then design and build a mask collector tool as the expected output.

2.2 STEM PaDL Lesson Exemplar Development

Sekolah Kebangsaan Minden Heights is a primary school in Penang, Malaysia. SK Minden Heights was selected as the trial school for the PaDL Framework after securing the approval of the school principal. This school is one of the partner schools of SEAMEO RECSAM for its community linkages and extension activities, and is the closest in terms of proximity which is ideal for ease in implementing activities either in-site or virtual with the teachers and students.

For the purpose of the trialling process, two mathematics and design teachers from SK Minden Heights participated in the Training of Trainers (TOT) on the STEM PaDL Framework at SEAMEO RECSAM on April 20 & 21, 2021. These teachers in turn conducted an orientation among their fellow science and mathematics teachers in the school. This orientation was related to the PaDL Framework and the trial of the framework with SK Minden Heights students.

A group of science and mathematics teachers were identified and organised to be the Lesson Demonstration Team, and a Grade 4 class (Key Stage 2) became the trial class. The Demonstration Team developed a lesson exemplar entitled "Used Face Masks: A Waste Management Crises". This was chosen to highlight the authentic social and health problem of discarded face masks during the COVID-19 pandemic experienced by the learners in Penang Island and across Malaysia. With this lesson, students experienced the "empathize" stage of the Design Learning model by exploring the problematic effects of indiscriminate disposal of face masks. The students "developed ideas to find solutions" on how to collect the used face masks scattered in the environment. The task included the idea that the students themselves should not become contaminated or be exposed to unhygienic practices when throwing away used face masks.

In the development of an integrated lesson plan to illustrate the STEM PaDL Framework, the project coordinator from RECSAM briefed the Demonstration Team about the use of the SEAMEO Common Core Regional Learning Standards (CCRLS) in Mathematics and Science (2017) published by RECSAM, as reference for the learning standards. Mapping of the learning standards was undertaken to identify point of entry or links with the face mask lesson.

2.3 STEM PaDL Lesson Exemplar

The following is the COVID-19 face mask problem scenario (see Figure 2.2) used in the lessons and the mapping to the SEAMEO CCRLS in Mathematics and Science.

Used Face Masks: A Waste Management Crisis

With the current pandemic swirling around us, most Malaysians now wear a face mask when they go out. In fact, it has become a must-have item. What is worrisome is that millions of these used face masks are being discarded indiscriminately. I have seen face masks strewn on pavements, in drains and on escalators. Even our beaches are not spared.

Besides being an eyesore, used face masks pose a public health risk. They may carry the COVID-19 virus, and so they should not be randomly discarded as normal waste. Think about it, should a contaminated face mask be discarded inside a confined space such as an elevator? No! The mask is a threat to people using the elevator.

Unfortunately, not many consider the face mask a hazardous waste and hence, pay little attention after its use. We have convinced most Malaysian to wear face masks when they are in public places. Let's go one step further by instilling in them the importance of disposing of used face masks in a responsible manner.

Adapted from: https://www.nst.com.my/opinion/letters/2020/05/594780/public-health-risk-discarded-face-masks

City Council

Waste Management Crisis

We need your help

Contaminated face masks are littering our streets and Penang Strait. We need you to design, and then create a model of a tool to collect contaminated masks for disposal.

Everyone needs to be more responsible with the disposal of their masks

Figure 2.2 COVID-19 face mask problem scenario.

2.4 Sample Curriculum Mapping

Linking the Face Mask to the Science Standards

Below is a sample curriculum map showing how the topic / lesson on face masks relates to the SEAMEO Common Core Regional Learning Standards (CCRLS) in Science and Mathematics across different Key Stages (Key Stage 1 – Grades 1 to 3; Key Stage 2 – Grades 4 to 6; Key Stage 3 – Grades 7 to 9).

Table 2.1
Curriculum Mapping of the CCRLS in Science for the Face Mask Lesson

Strand, Topic & Key Stage	Sub-topic	Learning Standards	Reference to CCRLS in Science	Point of Entry / Connection to Use of Face Mask
Strand: Life and the Living World **Topic: Personal Health and Healthy Lifestyle** Key Stage 2 (Grade 4 – 6)	***Hygiene and Safety at Home***	• Name some contagious diseases in everyday life • Explain various ways how the named diseases are spread • Suggest ways on how to prevent the spread of contagious diseases	Page 97 & 98	Contagious diseases spread by touching objects infected by the virus by asymptomatic patient; rubbing the eyes & lips; inhalation through the nose
Key Stage 3 (Grade 7 – 9)		• Explain how contagious diseases are treated and the effects of the treatment • Practice methods and measures in the prevention of contagious diseases		

Strand, Topic & Key Stage	Sub-topic	Learning Standards	Reference to CCRLS in Science	Point of Entry / Connection to Use of Face Mask
Human Organ System Key Stage 2 (Grade 4 – 6) Key Stage 3 (Grade 7 – 9)	***Human Sense Organs***	• Explain the functions of sensory organs • Describe the structure of sensory organs in humans • Explain the function of each part of the sensory organs	Page 100 & 101	Identity organs where virus could enter the body: skin by touching objects infected by the virus unconsciously by asymptomatic patient; rubbing the eyes, rubbing the lips, other than inhalation through the nose
Key Stage 2 (Grade 4 – 6)	***Human Respiratory System***	• Illustrate the path of air during inhalation and exhalation • Explain how the human breathing system works • Compare difference between inhaled air and exhaled air • State that oxygen inhaled is needed to produce energy from food	Page 100 & 101	Context: COVID 19 Why use face mask? What is the science behind wearing of the mask? https://www.healthline.com/health-news/the-simple-science-behind-why-masks-work

Strand, Topic & Key Stage	Sub-topic	Learning Standards	Reference to CCRLS in Science	Point of Entry / Connection to Use of Face Mask
Key Stage 3 (Grade 7 – 9)		• Identify the organs in the respiratory system of human beings • Describe the main function of the respiratory system • Describe the human breathing mechanism • Explain the transport of oxygen in the human body • Explain the gaseous exchange in the human body		COVID-19 is transmitted in the form of water droplets
Microorganisms Key Stage 2 (Grade 4 – 6)	***Infectious Diseases Caused by Micro-organism***	• Understand that some microorganism can cause infectious diseases and illnesses • Explain how common infectious diseases are spread through different modes of transmission • Explain ways to prevent the spread of diseases	Page 116 & 117	Viruses are acellular microorganisms, which means they are not composed of cells. Essentially, a virus consists of proteins and genetic material – either DNA or RNA, but never both- that are inert outside of host organism. Viruses are the smallest of all microbes

Strand, Topic & Key Stage	Sub-topic	Learning Standards	Reference to CCRLS in Science	Point of Entry / Connection to Use of Face Mask
		• Explain the importance of practicing healthy habits • Explain the meaning of the term immunization and vaccination • Name some common vaccines and identify the illness they cure		
Key Stage 3 (Grade 7 – 9)		• Explain how the human immune system responds to infectious diseases		
Human Health and Management Key Stage 2 (Grade 4 – 6)	***Prevention against Influenza, Measles, and Malaria***	• Explain the causes of influenza, measles and malaria • Describe the symptoms of influenza, measles and malaria • Practice health habits to prevent the spread of influenza, measles and malaria	Page 159	

Strand, Topic & Key Stage	Sub-topic	Learning Standards	Reference to CCRLS in Science	Point of Entry / Connection to Use of Face Mask
Key Stage 3 (Grade 7 – 9)		• Plan project-based activities to prevent the spread of influenza, measles and malaria		

2.5 Scheme of Work Outline

Table 2.2 below shows the scheme of work outline of the face mask STEM lesson for the PaDL Framework trialled at SK Minden Heights with the Grade 4 class (Key Stage 2).

Table 2.2
The Scheme of Work, Links to the Curriculum and Lesson Sequence for the Face Mask STEM Lesson

Scheme of Work Title	Time allocation	Grade / Year Level
Used Face Mask: A Waste Management Crisis	2 days	Key Stage 2 (Grades 4 – 6)

Unit Overview
In this unit, the students will gain understanding on the benefits of using face masks against COVID-19 and the dangers of contaminated face mask could afflict to the health of the citizens of the country. Students will explore on creating models and prototypes of tools to collect contaminated masks for safe disposal and thus reducing the risk of cross-contamination among the population of a given community. With their imagination and creativity, students will engage in design drawings and sketches on the suitable tool to collect used face masks using inexpensive local materials available at home to construct them. Students will apply their knowledge of measurement, angles, shapes, figures, and solids in creating their drawings, and sketches of 2D or 3D objects. Finally, students working in groups will present their prototypes / models and explain the design learning processes they went through until they reached the final version of their mask collector tool. The students will consider the current problem scenarios such as (i) not many people consider face mask as hazardous to human health, (ii) face masks are thrown on the ground or drain indiscriminately, and (iii) lack of inexpensive tools and safe methods for the disposal of contaminated masks.

Pre-requisite knowledge in Science
- Healthy Lifestyle Practices
- Human Organ Systems
- Infectious Diseases

Pre-requisite skills in Technology
- Drawing and Sketches
- Basic material science

Pre-requisite knowledge in Mathematics
- Numbers and Operations
- Quantity and Measurements
- Shapes, Figures and Solids
- Pattern & Data Representations

Useful Resources
- Newspaper reports and clippings
- National Geographic videos
- Statistics reports from Ministry of Health
- Websites

Assessment
- Formative assessment to assess understanding on the benefits of face masks and negative impact of contaminated face masks to the people and the environment
- Use of rubrics for the design of the tool to collect face mask
- Use of rubrics for the functionality of the developed face mask collector
- Use of rubrics for presentation skills

Links to Curriculum

TOPIC CONTENT

This lesson on Face Masks links with the topics below in reference to the *SEAMEO Common Core Regional Learning Standards (CCRLS)*

A. CCRLS in Science
- Hygiene and Safety at Home
- Human Sense Organ
- Human Respiratory System
- Infectious Diseases Caused by Microorganism
- Prevention against Influenza, Measles and Malaria

B. CCRLS in Mathematics
- Measurement and Relations
- Plane Figures and Space Solids
- Mathematical Process-Humanity

This lesson on Face Masks links with the topics below in reference to the Malaysian KSSR Year 4 Text book

Science: The Breathing of Human Life
Mathematics: Length
Design and Technology: Introduction to Design

ACHIEVEMENT OUTCOME 1:

Key knowledge	Key skills
• Exploring the health benefits of face mask • Realising of the danger caused by contaminated mask • Understanding the structure and function of the organ systems in protecting the body against infectious diseases • Practising daily healthy habits to protect one's body and other people against infectious diseases	• Observation • Research skills • Computational skills • Problem solving skills • Presentation skills

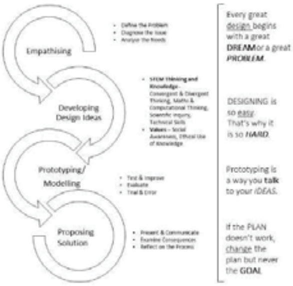
ACHIEVEMENT OUTCOME 2:

Key knowledge	Key skills
• Applying knowledge of measurement, angles, shapes, figures, and solids in creating their drawings, and sketches of 2D or 3D objects • Designing a new tool to collect the contaminated mask • Understanding material properties to build the new face mask collector	• Drawing, sketching skills • Technology skills • Using geometry skill to build suitable face mask collector • Evaluating suitable face mask collector design to make it more mobile

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
1	Teacher will show a video clip on the COVID-19 pandemic. Brief discussion - the teacher asks: How do you feel about the problem? What should we do to protect ourselves and other people against the COVID-19 pandemic? (The main idea here is to provide the context of the lesson and let students "empathise" with the severe cases of patients afflicted with COVID-19 and draw out the use of face masks).	Video analysis on the COVID-19 pandemic https://www.unicef.org/malaysia/stories/fight-coronavirus Example questions: • What health issue is the world facing now? • What are we doing to prevent these diseases? • Why should we wear masks? • How should we wear the mask correctly?	https://www.wmc-card.com/uk/the-importance-of-wearing-masks/ https://theconversation.com/single-use-masks-could-be-a-coronavirus-hazard-if-we-dont-dispose-of-them-properly-143007 https://www.nst.com.my/opinion/letters/2020/05/594780/public-health-risk-discarded-face-masks

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
2	Teacher will give the Problem Scenario (news clippings) to the students. To make the problem more dramatic and appealing to the students, the teacher will show the video. Teacher asks: What is the problem about? How do you feel? What information do you know? What other information do you want to know? How should you help in solving the problem of contaminated face masks? In pairs, students research the importance of mask in preventing spread of bacteria or virus, the types of masks, materials used in making masks, and cost of masks.	Analysis of the problem scenario via the newspaper clippings. Video analysis on the problem caused by improper disposal of masks. https://youtu.be/60vDnOeAcoA Search the internet for information about the face mask. Assessment (formative): Rate students' sharing of answers on the given questions. Examples of other protective materials (gloves and hand sanitizers). Assessment (formative): Evaluate students' understanding about the contaminated mask from the answer given.	https://www.independent.co.uk/life-style/face-masks-coverings-dispose-throw-away-safe-environment-litter-single-use-a9612946.html https://www.greenpeace.org/international/story/44629/where-did-5500-tonnes-of-discarded-face-masks-end-up/ https://youtu.be/T4KjcDgqpSc https://timesofindia.indiatimes.com/videos/motion-graphics/how-to-wear-use-take-off-and-dispose-a-face-mask/videoshow/74982175.cms

Lesson Sequence

Step	Teaching and Learning Activities	Learning Strategies, Teaching Considerations	Resources
3	Before the start of the sketch design and building of the tool to collect contaminated masks, students must understand the importance and the danger of improper mask disposal. Planning and generating ideas - design the tool to collect contaminated masks. Creating a design sketch / drawing of the mask collector tool. Understanding which material is suitable to be used to make the tool. Considerations: strength, lightweight, easy to carry around or even better collapsible and can be transported to other places easily.	Compare readily available materials at home. Establish mask measurements to determine minimum size using geometry. Ask students: How do we make the mask collector more affordable? Propose use of spreadsheet to record the steps undertaken to develop the tool. Example questions. • How long can we wear the same mask? • What do we do with the mask once we have used it? • Is the mask safe to be tossed in the rubbish?	

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
4	Developing the mask collector tool. Students will work individually to select the best sketch to develop the tool. Create a prototype tool using suitable material according to the design sketch. Students present and explain their prototype to other students.	Assessment (summative): assess the tool to collect contaminated mask Presentation skill: the students will be evaluated by their preparedness and their knowledge about the prototype tool. The tool does not need to work, but students need to describe their design idea and their imagination how it works.	
5	Teacher leads students to reflect on the whole learning experience of building the face mask collector.		

2.6 School Evaluation with Students

There is much research evidence from the fields of cognitive science, psychology and the neurosciences that drawing promotes cognition. A simple design sketch was the start of almost every work of art or artefact that is of value today across the globe. The significance of drawing a sketch is two-fold. Firstly, in the production of the object, and secondly in the kinds of thinking that make that object a reality. To draw a sketch, the mind needs to engage, develop, and integrate thoughts, feelings, actions, along with societal and cultural norms. Drawing a sketch is a critical skill for many 21st Century careers, as well as for daily life and communication.

Through STEM education that incorporates the inclusion of drawing a sketch, teachers can explore the students learning and thinking in terms of their ***knowledge*** and ***construction***. Knowledge does not necessarily mean content, but rather it is the principles that are depicted in the object's operation as communicated in the sketch and later in the pitch presentation. We initially explore student's knowledge through their sketch, and later as they describe their scenario solution. The student are making their thought processes visible through the sketch, so the details of the sketch show what the students considered important at that point in time. Thus, we need to ***educate to coordinate the eye and hand to make thinking visible***. Construction is what the students do to create the solution prototype. Often, we can explore the behavioural sequencing of the creation of the prototype to determine the students' logical thought processes. Below, we provide a description of the knowledge component of the sketch, followed by a brief consideration of construction.

2.6.1 Knowledge

Knowledge is communicated both verbally and visually. All individuals in the team contribute to the knowledge bank of ideas that are integrated to produce a solution to the scenario. As outlined in Chapter 1, the students share ideas as an initial strategy for determining a solution. This will usually begin with a discussion, and then as the discussion becomes complex, there is a need to incorporate a sketch into the discussion.

The simple '***line***' is the most basic form of drawing. It is the most versatile form of a mark on a page, and certainly the mark with the most potential. When multiple lines are joined together and a recognisable image appears, we have a '***sketch***'. A sketch is often considered to be the spontaneous image of what is being imagined, and can come alive with words or numbers of explanation. A sketch thus becomes ***a record of thinking and reasoning***.

In STEM education, we encourage sketching to be fast and free to capture the essence of the thoughts. We need to remember the task is '***drawing to design***', and not a visual arts task requiring aesthetic beauty or artistic skill – it is about the act of communication. This is reinforced to the student through the assessment criteria. The ***assessment criteria*** could include:

- ***life-likeness*** of the object in the sketch;
- ***detail*** and diversity of elements in the sketch;
- word or numerical ***labels*** and explanations; and
- the collaborative nature of STEM design and drawing to design.

Sketches generated as part of the design process have a number of characteristics. The sketch:

- is a form of ***communication*** of an object in visual form;
- is an image of an object and should include an ***end-function in mind***;
- is an image of an object that has a ***real-life value***;
- typically is created by a team of designers; and
- contain sufficient information ***to enable construction***.

A design drawing has thinking included in the sketch. The purpose and intention of the object is present in the design drawing implying the object's action.

Figure 2.3 below represents the essence of design drawing. The drawing is a representation of what the designer is imagining. It is a view of the designers' thinking.

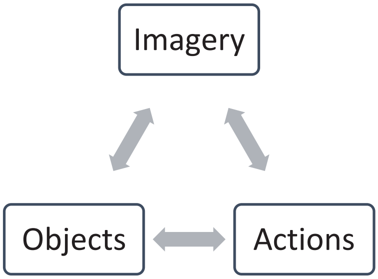


Figure 2.3 Drawing as design is an intellectually driven process.

The thinking that appears in the drawing is an image of an object with a real-world value and function. The image of the object is created from the accumulation of lines and marks on the page. It is the relationship between the lines and marks that gives meaning and action or purpose to the object. By looking at the relationships between the lines and marks, we see that design drawing is an intellectually driven process that is attempting to construct a 2-dimensional representation of an imaginary thought.

To draw a sketch is the ability to conceptualise a solution, visualise what the solution might look like, assess the viability of the visualisation, and reconceive the solution - all critical in the design process (see Figure 2.4). In the design thinking process, the students need to understand the task and scenario and imagine the solution. Then through active discussion among team members, the solution is visualised and a sketch is drawn. As the sketch becomes more complex, elements are added and removed through a collaborative process of continual assessing and editing of the sketch by the design team. Upon reaching a level of satisfaction with the sketch, the sketch of the design solution is considered complete, and the team is ready to move to prototype construction.

We have included the sketches created by six students who were part of the PaDL evaluation. These are presented in Figure 2.5. As described earlier in this chapter, it was not possible for students to work in teams due to the home learning necessary for COVID-19 safety. The sketches in Figure 2.5 are individual student sketches, drawn during class time and finessed after class.

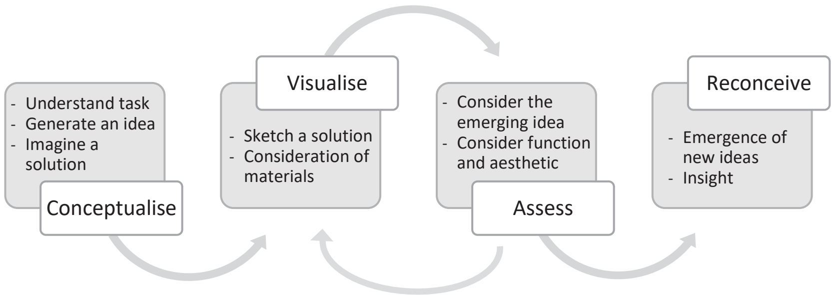


Figure 2.4 The 'drawing a sketch' thinking process.

In Table 2.3, we provide a brief analysis of these sketches, using a combination of the assessment criteria and sketch characteristics listed earlier in the chapter. An initial examination of Figure 2.5 indicates that the students were all able to effectively communicate an imagined object in a visual form.

Table 2.3
Assessment of the Sketch Samples

Characteristics as criteria	Sketch example
Life-likeness of the object in the sketch	Sketches A, B, C, and E are recognisable as some form of tool that would be able to pick up a discarded face mask. Sketches A, B, and C are ideas that recreate existing tools. Sketch C provides five solutions. Sketch E is innovative as it is repurposing an umbrella.
Detail and diversity of elements in the sketch	Sketch A contains length of stick. Sketches A, B, D, and E include structural and fastening details. Sketch F includes component details.
Word or numerical labels and explanations	Sketches A, B, C, D, E and F all include labels to provide explanations. Labels identify materials relating to: (a) what the object is to be made of (Sketches A, B, D, E), (b) as component fastenings (Sketches B, D), and (c) purpose (Sketches D [visually implied – mask near hook], F).
Object and should include an end-function in mind	Sketch D implies an end-function of collecting face mask by including a face mask. Sketch F explicitly includes end-function through a label – rubbish collector bin and the overall object.
Object that has a real-life value	Sketches A, B, C, D, E and F all include real-life value as a task solution. Some solutions are more practical or innovative than others.
Typically created by a team of designers	Not possible.
Contains sufficient information to enable construction	Sketches A, B, and D include a degree of construction thinking. Sketch A advises a hole is necessary where the 2 3-foot sticks join, but no joining mechanism is provided. Sketch B plans the use of rubber bands to hold a clothes clip to the cardboard handle. Sketch D uses straws to join ice cream sticks.

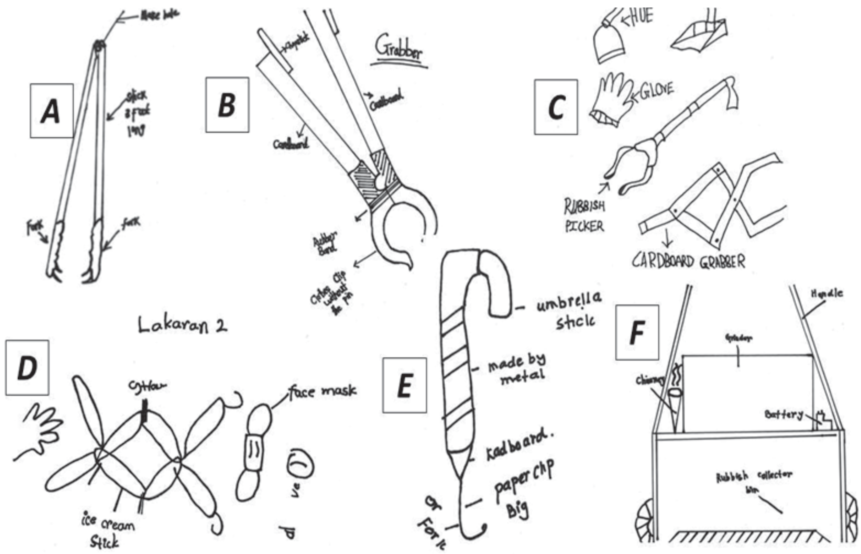


Figure 2.5 Examples of sketches drawn for the face mask activity.

2.6.2 Construction

The construction of the prototype is very exciting for the student teams. The thinking involved relates to creating a 3-dimensional model from the 2-dimensional sketch. The construction thinking process is described in Figure 2.6. The process is very similar to the drawing a sketch thinking process, however a key component of the construction thinking process is the incorporation of dexterity skills in the build. Figure 2.7 provides two mask-collector prototypes constructed form Sketches C and F in Figure 2.5.

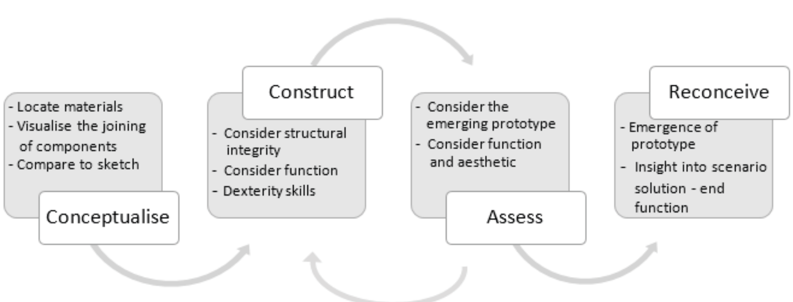


Figure 2.6 The construction thinking process.

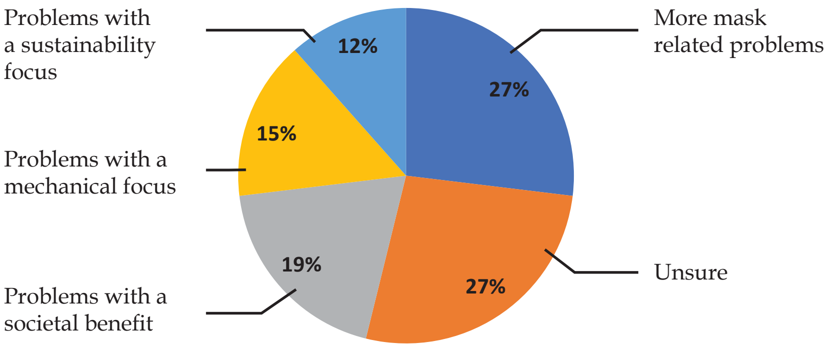
Figure 2.7 Mask-collector prototypes.

The students experienced the ***Conceptualise*** aspect both in the 'drawing a sketch' thinking process and in the construction thinking process. The two prototypes (C and F) bare resemblance to the sketches drawn by the students, indicating both students were referring to their sketches to complete the build. Prototype C has used cardboard and sticky-tape to create the hinge joints allowing the back-and-forth scissor actions of the cardboard grabber. The sketch indicated a hinge mechanism was needed, but the nature of that mechanism was not realised until the ***Construction*** had commenced. Structural integrity was assured through the thickness of the cardboard and the stabilising effect of the sticky-tape. The solution proposed by this student was a tool that was extendable and had an end-function of picking up the discarded masks without contaminating the user of the tool. Prototype F was constructed with care and attention for structural integrity in the handle and functioning wheels. There was a handle variation between Sketch F and the Prototype F indicating the student did ***Assess*** the need for one handle (on prototype) or two (on the sketch). The ***Reconceived*** end-function of the prototype is highly evident – use battery power to suck up the rubbish (face-mask) which is then collected in a bin before being ground up in a grinder and incinerated (smoke extracted through a chimney).

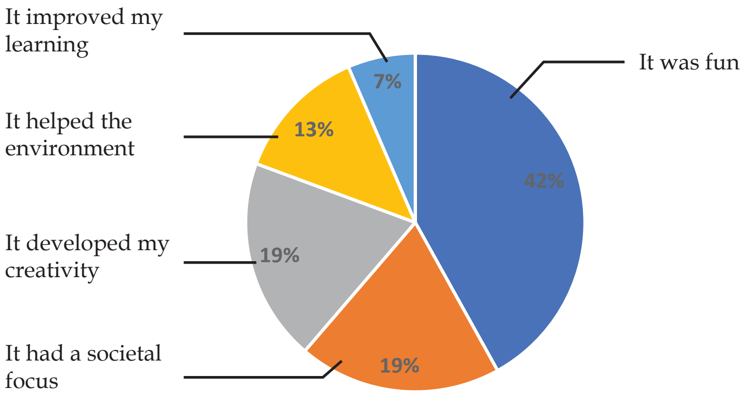
2.6.3 Learning Experience

The students were asked to complete a survey focusing on their learning experience using the STEM PaDL Framework. Below, we include a selection of their responses. The students were very engaged during the PaDL lessons. They were very keen to draw their sketches, but became very excited when told they were to build their design. It was this engagement and interest we probed in the survey.

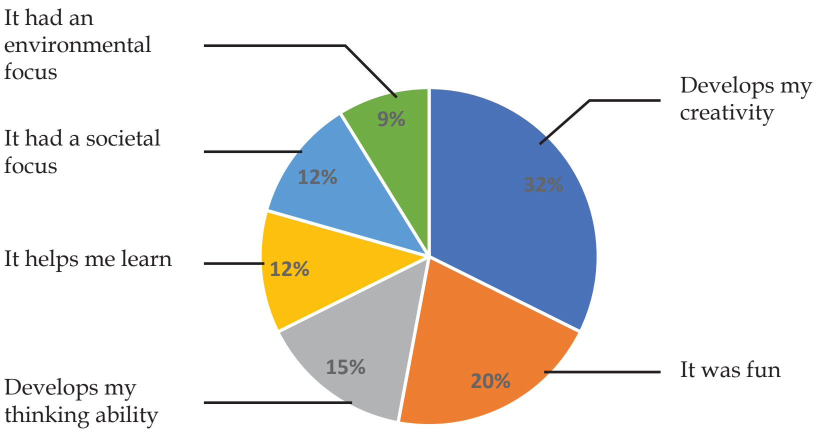
1. ***What different problem would you like to solve in a new design learning activity?***



2. ***Can you tell us why you like last week's activities of designing and developing the tool?***



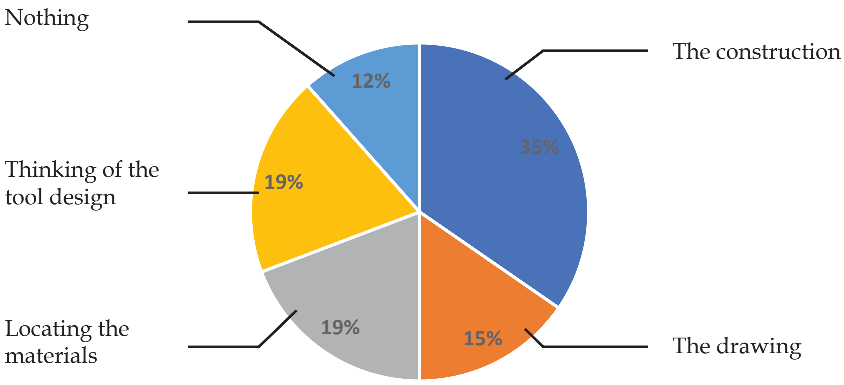
3. *I like this design learning activity because ...*



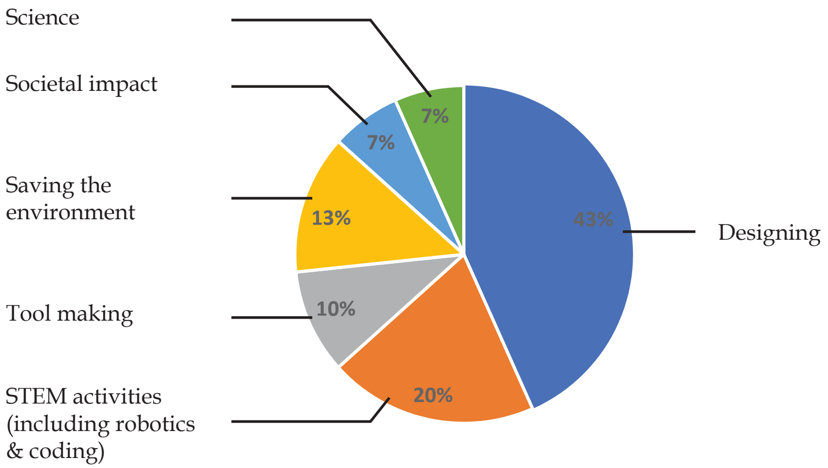
Questions 1, 2, and 3 revealed some students are very focused on society. They found merit in undertaking the activity of designing a tool to collect discarded face masks. They saw this action as one of assisting their community – having a societal benefit. Another group of students recognised the environmental or sustainability focus of the activity and wanted more opportunities with this focus.

The students were in upper primary school, yet they were aware that STEM learning through the PaDL Framework impacted on their creativity, thinking and learning development. Some found the imagining component (tool design) of the 'drawing a sketch' difficult, whilst others found the sketching interesting. The COVID-19 pandemic meant that the children could only access items they had in their homes, and were permitted to use. This provided a challenge for some students. The biggest challenge was found to be in the construction of the prototype. This was possibly due to the dexterity of the students having to work alone. Team members would have shared the workload, and contributed to the dexterity skill development. In addition to the earlier identified learning interest topics of society and the environment, students are very interested in design challenges and tool making. Robotics and coding are also a STEM interest.

4. *What was difficult about this design learning activity?*



5. *I want to learn more about ...*



Chapter 3

STEM Unit Exemplar: Tiger Conservation in Southeast Asia

Have your students undertake a design challenge to obtain better data about wild tiger populations. Use the problem scenario below.

> Over one-third of tiger conservation sites are severely at risk of losing their wild tigers - the majority of which are in Southeast Asia. Many of these areas lack basic plans for effective management. There is poor data collection and limited information about wild tiger populations.
>
> Government reports on the current status of national tiger recovery identify some best practice strategies and highlight many challenges.
>
> The key barriers to wild tiger recovery in Southeast Asia include poaching, lack of capacity, habitat loss and limited funding. Some countries have shown that despite these challenges, population recovery is possible alongside sustaining community livelihoods.
>
> To protect the remaining wild tiger populations, it is important for local communities to commit to changing the current situation, implement breeding recovery plans and improve data collection.
>
> Modified from: https://www.wwfindia.org/?18081/Urgent-attention-needed-for-global-tiger-recovery-efforts

Figure 3.1 Wild tiger conservation problem scenario.

3.1 Scheme of Work Outline

Table 3.1 shows the scheme of work for the tiger conservation STEM lesson. This was developed by a group of participants in the *Teaching to Transform* regional workshop comprised of: Ahmad Syihan Fadzli bin Khairi, Jerico F. Balmes, Koua Xiong, Mohd Muzaitulakmam bin Abdul Mutalib, Radin Muhd Imaduddin bin Radin Abdul Halim, Songka Keochansy.

Table 3.1
Scheme of Work, Links to Curriculum and Lesson Sequence for the STEM Lesson on Tiger Conservation in Southeast Asia

Scheme of Work Title	Time allocation	Year Level
Tiger Conservation in Southeast Asia	6 weeks	Key Stage 2

Unit Overview

The students learn about the human-tiger conflict in Southeast Asia, and help current scientists to improve their monitoring system to survey the tiger population and monitor their vital statistics such as height, length, weight and home territory.

The problems with the current system of catching and tagging a wild tiger include:

1. May require the tiger to be manually caught and measured, which is dangerous, and if the anaesthesia goes wrong or the involvement of inhumane treatment
2. Hard to measure data such as the weight, height and length and range. Can this be discretely and remotely collected without the tiger even knowing?

Pre-requisite knowledge:

1. Measurement: length, mass and volume
2. Endangered animals and habitats
3. Basic needs of water, food, water or shelter for animals
4. Basic material science and remote sensing

Useful Resources

1. Data and statistics from a trusted conservation officials or government
2. World Wildlife Fund for Nature (WWF) resources on the Internet
3. Interviews and dialogue recorded with experts such as WWF, local conservation managers and nature societies
4. Magazine, local newspaper clippings about tigers
5. Public videos by groups such as WWF or National Geographic

Assessments
Refer to lesson teaching plan

Links to Curriculum	
TOPIC CONTENT	
This topic includes: (by referring to Common Core Regional Learning Standards in Mathematics and Science) 1. Quantity and Measurement (Key Stage 1) 2. Pattern and Data Representation (Key Stage 1) 3. Measurement of Volume with surface area (Key Stage 2, Strand – Measurement & Relations) 4. Data handling and graphs (Key Stage 2) 5. Body parts of animal (Key stage 1 & 2) 6. Basic need of animals	
ACHIEVEMENT OUTCOME 1:	
Key knowledge	**Key skills**
1. Exploring the physical characteristics of a tiger 2. Realisation of decreasing number of tigers in Asia	1. Observation 2. Computational and graphing skills 3. Measuring skills
ACHIEVEMENT OUTCOME 2:	
Key knowledge	**Key skills**
1. Designing a new cage to operate capture-tag-monitor 2. Utilising electrical circuitry to obtain captured tiger vital health statistics 3. Understanding material properties to build the new cage	1. Using geometry skill to build suitable cage dimension 2. Evaluating suitable cage design to make it more mobile
ACHIEVEMENT OUTCOME 3:	
Key knowledge	**Key skills**
1. Biological needs of tiger 2. Conservation of endangered animal	1. Research 2. Presentation 3. Technology

Overall Learning Sequence					
Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Watch human-tiger conflict video as induction set. Research on endangered species and reason for the decline, especially Southeast Asian tigers.	Visit local zoo to watch a tiger. Understand the basic physical characteristics and locomotion of a tiger. Aware of the difficulty to track and measure a tiger.	Design a system to discretely photograph and measure a tiger. Consider how to do this humanely, discretely and safely.	Prototype an automated tiger camera system. Consider how to remotely measure tiger biometric data (weight, height, length, speed.) Empathy and biomechanical engineering.	Examine tiger data to predict suitable place to set up the camera hide. Use data to predict location and tiger behaviour then defend habitat.	Evaluation including presentation and reflection. Identify ways to protect endangered tigers. Feedback from teacher and expert.

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
1	Students will be grouped in pairs to research on human-tiger conflict in Southeast Asia using the internet and share their findings with the class. The sharing will include: • examples of other endangered animals • different species of tigers • current estimates of wild tigers left in the world / Asia Consider how we collect data about animals and estimate population sizes.	Invite speakers from WWF for Nature, read books or internet research to determine, Examples of other endangered animals. • other endangered species of tiger • estimate of Southeast Asia tiger population left in the wild • Describe how current estimate are collected Graphing data to track dwindling number of tigers. **Assessment (formative):** Rate student answers to questions and graphs	Species Directory page WWF https://www.worldwildlife.org/species/directory Wild Tiger Numbers (2016) New York Times. https://www.nytimes.com/2016/04/12/world/asia/wild-tiger-numbers-are-rising-wildlife-groups-say.html Video to Catch and Tag a Tiger (2015) 4 min YouTube https://www.youtube.com/watch?v=dbw5TkSFENs

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
2	Watching a tiger Before we start building the camera hide, students must understand the physical characteristics of a tiger • What is the average height and weight of tigers? • What is their diet? • Where do they live? • How do we differentiate between tigers (stripes as a fingerprint)? These points will give later clues about how to find a tiger and where to position the camera hide.	Plan a virtual or physical visit to a zoo (if practical). Prepare a list of question for students to interview zoo keeper or tiger expert. Record a brief video to watch later that shows tigers on move. Practice sketching and writing a zoo journal or field notes. Calculate the tiger size from the print size and stride length. Make a sketch from a photo or cast a mould of an animal track using plaster. **Assessment (formative):** Students' understanding of tiger physical characteristics using a list of questions prepared in advance.	Question examples: • What is an average height and weight of a tiger? • By looking at the mouth of a tiger, predict what is its diet? • Where is tiger's natural habitat? • How can we differentiate between tigers? Tiger Habitats page https://www.tigers.org.za/tiger-habitats.html Using electronic animal tags (2018) 9 min YouTube https://www.youtube.com/watch?v=iSQBTbDrSs8 Plaster cast footprint (2020) 5 min YouTube https://www.youtube.com/watch?v=GL6gG9O3YAQ

Lesson Sequence

Step	Teaching and Learning Activities	Learning Strategies, Teaching Considerations	Resources
3	Measuring a tiger Consider the empathy of a tiger in the wild and how to humanely record them. Design a hide that can record a passing tiger to help track. Sketch a prototype design and annotate to show • camouflage or disguise • shape and size • mechanics to operate • trigger system to record • material used to construct Suggest how we can obtain tiger vital statistics: weight, length, height, speed without human intervention. Research about humane treatment of wild animals then ask students how to humanely record a tiger.	Ask students: how do we make prototype humane for tigers and safe for humans? Suggest an innovative way to safely and humanely track a tiger. This may include • collar with GPS tracker • ear tag or skin implant • remote camera system Collect tiger size and stride dimensions and figure out prototype using geometry. **Assessment (formative):** Students' understanding of tiger empathy and research skills and their submission of a prototype device to record and track a tiger.	Tiger Locomotion (2018) 2 min YouTube https://www.youtube.com/watch?v=rxRoPTp5UHo Tigers running fast (2014) 4 min YouTube https://www.youtube.com/watch?v=Ldz2eB2zSvY 

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
4	Building a Prototype Understanding tiger anatomy and suggesting new way to track or measure a tiger. Consider the • hide location and position • robust for use in the field • lightweight, easy to carry • collapsible, easy to move	Students refer to field notes of tiger locomotion, behaviour and consider empathy about humanely treating a tiger. Students design and create a prototype model of their solution to track and measure tigers. The prototype does not have to work but it should help explain how it will work. **Assessment (formative):** Students submit a prototype or model of their tracking device along with a detailed explanation about how it will work.	Tracking collars for wildlife https://wildlifeact.com/blog/gps-and-vhf-tracking-collars-used-for-wildlife-monitoring/ Tracking tigers is dangerous (2016) 2 min YouTube https://www.youtube.com/watch?v=09I4sK3Ux-E What is a Prototype? (2015) 4 min YouTube https://www.youtube.com/watch?v=4XenqN5Ib9o

Lesson Sequence

Step	Teaching and Learning Activities	Learning Strategies, Teaching Considerations	Resources
5	Examine tiger movement behaviour to decide where to deploy your prototype. Since the class does not have access to real wild animals or GPS tracking data, we can simulate the roaming behaviour of a wild tiger to local cats or other animals using a map and real observations made over a week. Students can learn how to record field notes.	Whilst a tiger is a solitary animal, students can watch a video to observe and describe different tiger behaviours. With the help of a zoo expert / keeper, access biometric data (weight, height, length, etc), about a range of different tigers and copy into a spreadsheet to graph, sort and interpret. **Assessment (formative):** Spreadsheet submission and data interpretation. Perhaps a graph of the data or field log entries.	**Field notes** keep track of observations that you may forget over time. They record details of time, date, location, weather, tiger observations and behaviour, any conversations. A zoo expert can help you with a template The wonders of animal tracking (2020) YouTube https://www.youtube.com/watch?v=0SbZfLOUcj0 Where art meets exploration (2021) 8 min YouTube https://www.youtube.com/watch?v=vS1VTBI_FN0

Lesson Sequence			
Step	**Teaching and Learning Activities**	**Learning Strategies, Teaching Considerations**	**Resources**
6	Evaluation including presentation and critical reflection. Feedback from other students, teacher and/ or expert.	Students to showcase their design prototypes and give a presentation about their learning. **Assessment (summative):** Zero point Rubric (check list) for the following : • Tiger observation data • Tiger biometric data • Prototype design • Tracking System Prototype • Class presentation skills • Critical reflection	Elevator pitches for scientists https://medschool.vanderbilt.edu/wp-content/uploads/sites/9/files/public_files/Elevator%20Pitches%20for%20Scientists_Uyen_0.pdf 

3.2 Curriculum alignment with CCRLS + Other countries teaching standards

The tables below show the curriculum alignment of the STEM lesson on tiger conservation with CCRLS in Mathematics and Science and from Malaysia's Science curriculum standards.

3.2.1 Mathematics

Table 3.2
Curriculum Alignment of the Tiger Conservation Lesson with CCRLS in Mathematics

Topics	Reference
Strand: Shapes, Figures, and Solids *Key Stage 1* • Exploring Shapes of Objects *Key Stage 2* • Extending Measurement of Volume in Relation to Surface	Page 25, 41
Strand: Pattern and Data Representations *Key Stage 1* • Collecting Data and Representing Structure	Page 27
Strand: Data Handling and Graphs *Key Stage 2* • Arranging Tables for Data Representations • Drawing and Reading Graphs for Analysing Data	Page 47 & 48
Strand: Mathematical Processes – Humanity *Key Stage 3* • Utilising ICT tools as well as notebooks and other technological tools • Producing valuable explanations based on established knowledge, shareable representations and examples • Utilising notebooks, journal books and appropriate ICT tools to record and find good ideas and share with others • Preparing and presenting ideas using posters and projectors to promote good practices in the community • Listening to other's ideas and asking questions for better designs • Utilising information, properties, models and visible representations as the basis for reasoning	Page 52 & 53

3.2.2 Science Inquiry

Table 3.3
Curriculum Alignment of the Tiger Conservation Lesson with CCRLS in Science

Topics	Reference
Topic: The World of STEM Sub-topic: How STEM works *Key Stage 1* • Explain the importance of STEM in everyday life *Key Stage 2* • Aware of the applications of science in everyday life *Key Stage 3* • Identify scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity • Aware of the nature / processes of science and engineering design process • Aware of arguments develop from evidence and interpretation of evidence	Page 96
Topic: Living Things and Non-Living Things Sub-topic: Characteristics of Living Things and Non-Living Things *Key Stage 1* • Identify the basic needs of living things – air, water, food	Page 98
Topic: Animals Sub-topic: Body Parts of Animals *Key Stage 1* • Identify the main parts of the body of animals *Key Stage 2* • Explain that the characteristics of body parts of animals are suited to where they live	Page 107

Topics	Reference
Topic: Animals Sub-topic: Basic Needs of Animals *Key Stage 1* • State the basic needs of animals • Describe the food sources for animals • Identify shelter for animals *Key Stage 2* • Understand the importance of survival of animals	Page 107
Topic: Animals Sub-topic: Animal Movements *Key Stage 1* • Describe the different kinds of animal movements • Understand the importance of animal movements	Page 108
Topic: Animals Sub-topic: Endangered Animals and Conservation *Key Stage 2* • Identify endangered animals by giving examples • Explain why animals become endangered in their natural habitat • Give examples of extinct animals • Explain why certain animals are facing the threat of extinction	Page 110

3.2.3 Technology and Engineering

Table 3.4
Curriculum Alignment of the Tiger Conservation Lesson with Technology and Engineering Standards

Topics	**Reference**
Learn how to use Microsoft PowerPoint	"World of Science and Technology" Malaysian Science and Technology Curriculum Standard for Year 2, pp. 33 – 49
Solving problems and make decisions using Microsoft Excel	"World of Science and Technology" Malaysian Science and Technology Curriculum Standard for Year 3, pp. 47
Stability and strength of a structure (camera hide design)	"Science" Malaysian Science Curriculum Standard for Year 4, pp. 79 (Chapter: Technology)

Chapter 4

Theme-focused STEM Unit Ideas

There are nine theme-focused STEM units included in this chapter, with curriculum links to science and mathematics (CCRLS) and technology and engineering as well as to the United Nations Sustainable Goals (SDGs). These theme-focused ideas are adapted from the STEM units created by the different table groups at the *Teaching to Transform* regional workshop. The overall student design learning sequence and some suggested activities are presented. It is your turn to adapt and extend these ideas for your own teaching. Do share your teaching experiences and your students' learning experiences with us.

For sure you are already aware of the United Nations Sustainable Development Goals (SDGs) presented in Figure 4.1. The 17 UN SDGs are as follows:

1. No Poverty
2. Zero Hunger
3. Good Health and Well-Being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships for the Goals

Any of the goals can be used as a theme to develop STEM units. The SDGs used in the STEM units in this chapter are underlined.

Figure 4.1 The 17 United Nation Sustainable Development Goals.

4.1 Renewable Energy at Home

Table 4.1
Theme-focused STEM Idea Lesson on Renewable Energy at Home

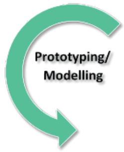
Renewable Energy at Home		
UN Sustainable Development Goal:	SDG #7 – Affordable and Clean Energy (https://sdgs.un.org/goals/goal7)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will become aware of the input and issues related to energy crisis to mankind due to the depletion of non-renewable sources of energy. • Students will be prompted to explore the available sources of renewable energy. • Students will be using the Internet and other reading materials (e.g., library, textbooks) to find out what are the advantages and disadvantages of different renewable energy sources, with evidence. • Students will be tasked to create projects that uses a low-cost alternative energy source that can replace our home appliances.	**Empathising** 	• Watch and analyse a video on energy usage and the depletion of non-renewable energy. • Discuss the energy crisis. • Present and relate their discussion to the impact. • Definition of renewable and non-renewable energy sources, with examples. • Explore using internet about the advantages and disadvantages of different energy sources. • Stimulate with an article with statistical data showing the usage of energy in the real world. • Investigate what are the sources of energy use in their homes, and whether they are renewable or non-renewable.

<table>
<tr><th colspan="3">Renewable Energy at Home</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #7 – Affordable and Clean Energy (https://sdgs.un.org/goals/goal7)</td></tr>
<tr><th>Unit Objectives Overview</th><th colspan="2">Suggested Learning Experiences</th></tr>
<tr>
<td rowspan="3">Curriculum Links

Sciences
• Identify renewable and non-renewable sources of energy
• Evaluate the benefits and risks when using various sources of energy to generate electricity and consider their impact to the environment

Technologies
• Use Internet data for the discussion of sustainable development
• Use graphing tool for comparison of the graph and knowing properties of function
• Use projector for sharing ideas such as project survey, reporting and presentation

Engineering
• Design a model to implement practical green living in real life context
• Design products related to the solution of problems associated with the impact of modernisation on the environment</td>
<td>Developing Design Ideas

</td>
<td>• Design a low-cost model of alternative energy source appliance at your home
• Researching previous solutions and annotate / test if they will work in context
• Draw, ideate etc</td>
</tr>
<tr>
<td>Prototyping / Modelling

</td>
<td>• Produce a prototype of the low-cost model of alternative energy source appliance at your home
• Create, test and improve parts of your model (minimum three iterations)</td>
</tr>
<tr>
<td>Proposing Solutions

</td>
<td>• Present
• Demonstrate
• Conduct peer assessment
• Reflect
  ○ What have we learned?
  ○ Record reflection of our learning journey (content, skills, values, conclusion)</td>
</tr>
</table>

Renewable Energy at Home	
UN Sustainable Development Goal:	SDG #7 – Affordable and Clean Energy (https://sdgs.un.org/goals/goal7)
Unit Objectives Overview	**Suggested Learning Experiences**
Mathematics • Designing models for sustainability using mathematics • Enjoying problem solving through various questioning for extension of operations into algebra, space and geometry, relationship and functions, and statistics and probability • Using diagrams for exploring possible and various cases logically • Utilising tables, graphs and expressions in situations	

4.2 Sustainable Aquaponic Gardens

Table 4.2

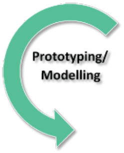
Theme-Focused STEM Idea Lesson on Sustainable Aquaponics Gardens

Sustainable Aquaponic Gardens		
UN Sustainable Development Goal:	SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will identify healthy and unhealthy food. • Students will list reasons why some foods are healthy and unhealthy for the body. • Students will state the importance of healthy food. • Students will explain how to handle, keep and eat food safely. • Students will investigate the importance of water, air and light to plants through simple research.	**Empathising** 	• Identify the problem relating to food security. • Use technology to explore healthy food. • Present findings using information and communications technology

<table>
<tr><th colspan="3">Sustainable Aquaponic Gardens</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)</td></tr>
<tr><td>Unit Objectives Overview</td><td colspan="2">Suggested Learning Experiences</td></tr>
<tr><td>Curriculum Links

Sciences
• Identify healthy and unhealthy food and give examples
• Evaluate and practise the habits of healthy eating
• Identify the basic needs of living things – air, water, food
• Identify renewable and non-renewable sources of energy
• Conduct research and make a presentation to illustrate evidence of green living in real life context

Technologies
• Use Internet data for the discussion of sustainable development
• Use graphing tool for comparison of the graph and knowing properties of function
• Use projector for sharing ideas such as project survey, reporting and presentation</td><td>Developing Design Ideas
</td><td>• Plan the garden
○ Brainstorm the design of the garden, how can we make it sustainable?
○ Research existing solutions and annotate / test if they will work in context.
○ Consider the costs, the kind of plants that are easy to grow, quality of soil, composting, fertiliser, aquaponic system, what kind of fish are suited to live in an aquaponic system?
○ Field trip to agency related to bionic garden.
• Design the garden
○ Draw each of the possible solutions for an aquaponic garden, including labels for required materials, measurements, the chosen plants and fish species, and other elements of the design.</td></tr>
</table>

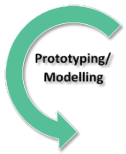
Sustainable Aquaponic Gardens		
UN Sustainable Development Goal:	SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Engineering • Design a model to implement practical green living in real life context • Design products related to the solution of problems associated with the impact of modernisation on the environment **Mathematics** • Designing models for sustainability using mathematics	**Prototyping / Modelling** 	• Produce a prototype of the aquaponic garden for your home or community. • Test and improve each part of the model (minimum three iterations) • Observe, record and explain what is happening in the system, analyse risks and plan for re-design. • Re-design / improve project, creating a final model of proposed solution.
• Using diagrams for exploring possible and various cases logically • Enjoying problem solving through various questioning for extension of operations into algebra, space and geometry, relationship and functions, and statistics and probability • Enjoying measuring space using calculations with various formulas	**Proposing Solutions** 	• Present the solution. • Demonstrate how it works. • Conduct peer assessment – respond to feedback. What are the strengths and areas for improvement on this design? • Reflect ○ What have we learned?

4.3 Managing Pests in Our Homes

Table 4.3
Theme-focused STEM Idea Lesson on Managing Pests in Our Homes

Managing Pests in Our Homes		
UN Sustainable Development Goal:	SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will identify and classify pest animals according to observable characteristics including type, habitat, feeding pattern, and natural biological context. • Students will conduct a census to establish pest population size, feeding habits and behaviour. • Students will integrate technology and engineering concepts in the design and construction of a no-harm pest trap.	**Empathising** 	• Identify household pests as a bioecological problem relating to food safety, security and sanitation. • Conduct a census to collect data and describe the pest population, feeding habits, behaviour and natural biological context of the animals. • Contrast animals needs and habits in their natural biological context as compared with the human habitats using a Venn diagram. • Establish the pest animals' reproduction rate through analysis of population growth (i.e., exponential). • Present findings using information and communications technology.

Managing Pests in Our Homes		
UN Sustainable Development Goal:	SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Curriculum Links **Sciences** • Investigate how pests and diseases affect common crops • Investigate different methods of pest control • Observe and explain behaviour of humans and animals in response to internal and external stimuli • Describe adaptations or special characteristics in animals which protects them from danger against enemies • Explain that the characteristics of body parts of animals are suited to where they live **Technologies** • Use graphing tool for comparison of the graph and knowing properties of function • Use projector for sharing ideas such as project survey, reporting and presentation	**Developing Design Ideas** 	• Design a trap for a specific pest: ○ Brainstorm the design of the trap ○ Research existing solutions and annotate / test if they will work in context ○ Consider costs, available materials, methods of no-harm trapping and needs of the animal while in the trap (e.g., food, water). • Design the trap. • Draw each of the possible solutions for a no-harm trap, including labels for required materials, measurements, and elements of the design.

Managing Pests in Our Homes		
UN Sustainable Development Goal:	SDG #2 – Zero Hunger (https://sdgs.un.org/goals/goal2)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Engineering • Develop and design complex solutions to problems based on evidence and data collected from investigations • Design products related to the solution of problems associated with the impact of modernisation on the environment **Mathematics** • Designing models for sustainability using mathematics • Using diagrams for exploring possible and various cases logically • Utilising tables, graphs and expressions in situations • Enjoying measuring space using calculations with various formulas	**Prototyping / Modelling** 	• Produce a prototype of the no-harm trap for your home or community. • Test and improve each part of the model (minimum three iterations). • Observe, record and explain the effectiveness of the trap, analyse risks and plan for re-design. ○ Re-design / improve the pest trap, creating a final model of proposed solution.
	Proposing Solutions 	• Present the solution. • Demonstrate how it works. • Conduct peer assessment- respond to feedback. What are the strengths and areas for improvement on this design? • Reflect ○ What have we learned?

4.4 Reducing Plastic Pollution in Our Water Ways

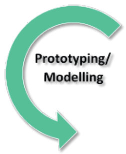
Table 4.4

Theme-focused STEM Idea Lesson on Reducing Plastic Pollution in Our Water Ways

Reducing Plastic Pollution in Our Water Ways		
UN Sustainable Development Goal:	SDG #14 – Life Below Water (https://sdgs.un.org/goals/goal14)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will understand the impact of pollution on the environment. • Students will explore the properties and composition of plastic and why it is non-biodegradable. • Students will collect data about plastic pollution and use digital technologies to represent their findings in a graph. • Students will implement an engineering design process to reduce, reuse or recycle plastic waste.	**Empathising** 	• Read articles and watch documentary on the impact of plastic on animals living in the water. • Collect evidence such as photographs and samples of plastic pollution. • Sort the materials into plastics and non-plastics using a Venn diagram, and quantify the materials (i.e., how many bottles, caps, straws). • Conduct experiment to test the biodegradability of plastic by testing how the properties of plastic change when heated. • Students to design experiment to investigate the impact of plastic pollution on fish (e.g., fish dissection). • Present findings using information and communications technology.

Reducing Plastic Pollution in Our Water Ways		
UN Sustainable Development Goal:	SDG #14 – Life Below Water (https://sdgs.un.org/goals/goal14)	
Unit Objectives Overview	**Suggested Learning Experiences**	

Curriculum Links
Sciences
• Describe the impact of water pollution on the Earth's water resources
• Explain the impact of polluted water on animals
• Conduct research and suggest ways to address the negative effects of human activities on the environment
• Suggest solutions to problems associated with pollution, global warming, and water resources
 	
Technologies
• Use Internet data for the discussion of sustainable development
• Use graphing tool for comparison of the graph and knowing properties of function
• Use projector for sharing ideas such as project survey, reporting and presentation
	Developing Design Ideas
	
		• Design a solution to reduce, reuse or recycle plastic waste.
		  ○ Brainstorm and generate ideas
		  ○ Research existing solutions and annotate / test if they work in context
		  ○ Consider costs, tools, materials, methods and needs of stakeholders.
		• Draw some of the possible solutions for a house made of recycled plastic waste, and label materials, measurements, and elements of the design.

	Prototyping/ Modelling 	• Produce a prototype of the design for your home or community • Test and improve each part of the model (minimum three iterations) • Observe, record and explain the effectiveness of the design • Creating a final model of proposed solution.

Reducing Plastic Pollution in Our Water Ways		
UN Sustainable Development Goal:	SDG #14 – Life Below Water (https://sdgs.un.org/goals/goal14)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Engineering • Design a product using technology to improve the quality of life • Design products related to the solution of problems associated with the impact of modernisation on the environment **Mathematics** • Designing models for sustainability using mathematics • Using diagrams for exploring possible and various cases logically • Utilising tables, graphs and expressions in situations • Enjoying measuring space using calculations with various formulas	**Proposing Solutions** 	• Conduct an exhibition to showcase the prototype to the school and community. • Respond to feedback, what are the strengths and areas for improvement? • Reflect on the process and present findings.

4.5 Counteracting Air Pollution in Our Communities

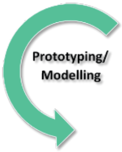
Table 4.5
Theme-focused STEM Idea Lesson on Counteracting Air Pollution in Our Communities

Counteracting Air Pollution in Our Communities		
UN Sustainable Development Goal:	SDG #13 – Climate Action (https://sdgs.un.org/goals/goal13)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will understand the causal relationship between air pollution, the greenhouse effect and global warming. • Students will understand the impact of the greenhouse effect and global warming on humans, animals and the environment. • Students will conduct a case study on CO_2 emissions and present their findings in a graph using digital technologies. • Students will implement an engineering design process to design a solution that addresses air pollution and greenhouse gas emissions.	**Empathising**  	• Explore the effects of air pollution and relationship with the greenhouse effect and global warming through reading articles and watching videos, such as rising sea levels and increased frequency of natural disasters and the impacts on humans, animals, and the environment. • Collate data from the Air Index, population size and CO_2 emissions and create a graph showing the relationship between these factors. • Engage with information and videos or podcasts about the causes of air pollution and greenhouse gases such as vehicle emissions and energy production. • Visit a forest and conduct a case study, measuring CO_2 in the forest and at school. • Present findings using information and communications technology.

<table>
<tr><th colspan="3">Counteracting Air Pollution in Our Communities</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #13 – Climate Action
(https://sdgs.un.org/goals/goal13)</td></tr>
<tr><td>Unit Objectives Overview</td><td colspan="2">Suggested Learning Experiences</td></tr>
<tr><td rowspan="2">Curriculum Links

Sciences
• Illustrate how human activities affect the atmosphere and the build-up of greenhouse gases (GHGs)
• Interpret and explain how global temperature affects the atmospheric gases and alter the atmospheric functionalities
• Analyse the composition of polluted air and the effects of various air pollutants

Technologies
• Use Internet data for the discussion of sustainable development
• Use graphing tool for comparison of the graph and knowing properties of function
• Use projector for sharing ideas such as project survey, reporting and presentation</td>
<td>Developing Design Ideas

</td>
<td>• Design a solution to reduce air pollution in our communities.
○ Brainstorm and generate ideas
○ Research existing solutions and annotate / test if they work in context
○ Consider costs, tools, materials, methods and needs of stakeholders.
• Draw some of the possible solutions for creating a living wall, and label materials, measurements, and elements of the design.</td></tr>
<tr><td>Prototyping / Modelling

</td>
<td>• Produce a prototype of the design for your community
• Test and improve each part of the model (minimum three iterations)
• Observe, record and explain the effectiveness of the design
• Redesign the product based on findings.
• Create a final model of proposed solution.</td></tr>
</table>

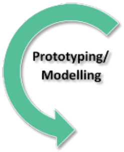
Counteracting Air Pollution in Our Communities		
UN Sustainable Development Goal:	SDG #13 – Climate Action (https://sdgs.un.org/goals/goal13)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Engineering • Design a model to decrease the effects of air pollutants • Design products related to the solution of problems associated with the impact of modernisation on the environment **Mathematics** • Enjoying problem solving through various questioning for extension of operations into algebra, space and geometry, relationship and functions, and statistics and probability • Using diagrams for exploring possible and various cases logically • Utilising tables, graphs and expressions in situations	**Proposing Solutions** 	• Present final prototype to peers and / or community members for evaluation and feedback. • Respond to feedback, what are the strengths and areas for improvement? • Reflect on the process and present findings.

4.6 Food Hygiene for Healthy Living

Table 4.6
Theme-focused STEM Idea Lesson on Food Hygiene for Healthy Living

Food Hygiene for Healthy Living		
UN Sustainable Development Goal:	SDG #3 – Good Health and Well-Being (https://sdgs.un.org/goals/goal3)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will become aware of the issues relating to the consumption of food that is not fresh or not properly prepared. • Students will explore how to handle, keep and eat food safely. • Students will choose a local problem to solve about food hygiene, for example, in the hawker centre food stall, How do you prevent the flies from gathering and contaminating the food? • Students will evaluate and practise the habits of food hygiene through designing and testing a prototype to solve the problem.	**Empathising**  	• Pose questions about consuming foods that are not fresh. • Investigate case studies from news and social media. • Discuss the wicked problem relating to social expectations, legislation or laws relating to hawker foods, and health issues. • Visit a local hawker centre or market and / or conduct role-plays in class to demonstrate the problems of maintaining food hygiene in different contexts, such as at a fresh fish stall, hawker centre food stall, or a restaurant. • Pose questions about maintaining the hygiene of foods and brainstorm a problem to solve (e.g., design a mechanism for swatting away flies, or a way to keep foods hygienic and presentable to customers at a hawker centre).

<table>
<tr><th colspan="3">Food Hygiene for Healthy Living</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #3 – Good Health and Well-Being (https://sdgs.un.org/goals/goal3)</td></tr>
<tr><th>Unit Objectives Overview</th><th colspan="2">Suggested Learning Experiences</th></tr>
<tr><td rowspan="2">Curriculum Links

Sciences
Explain how to handle, keep and eat food safely
Explain the causes of diarrhea and ways to prevent it
Suggest ways on how to prevent the spread of certain diseases
Technologies
Utilising ICT and other technological tools such as microbits
Coding microbits or other tools to create a motion detector or traps or a mechanism for swatting flies
Use projector for sharing ideas such as project survey, reporting and presentation
Engineering
Design a model to solve the identified problem (e.g., to trap or reduce flies and other pests that affect food hygiene)
Design products related to the solution of problems associated with the impact of modernisation on the environment</td><td>Developing Design Ideas
</td><td>Design a solution to the problem identified in the empathising stage.
Brainstorm and generate ideas.
Research existing solutions and annotate / test if they work in the context.
Consider costs, tools, materials, methods and needs of stakeholders.
Draw some of the possible solutions and label materials, measurements, and elements of the design.</td></tr>
<tr><td>Prototyping/ Modelling
</td><td>Produce a prototype of the design.
Test and improve each part of the model (minimum three iterations).
Observe, record and explain the effectiveness of the design.
Redesign the product based on findings.
Create a final model of proposed solution.</td></tr>
</table>

Food Hygiene for Healthy Living	
UN Sustainable Development Goal:	SDG #3 – Good Health and Well-Being (https://sdgs.un.org/goals/goal3)
Unit Objectives Overview	**Suggested Learning Experiences**
Mathematics • Solving problems through exploration, inquiry, conjecturing, justifying, proving, representation and sharing • Using numbers, measurement, and shapes • Appreciating others' ideas, meaningful elaboration, discussions of usefulness and efficiency • Developing values of reasonableness and harmony	**Proposing Solutions**  • Present the final prototype to peers and / or community members for evaluation and feedback. • Respond to feedback, what are the strengths and areas for improvement? • Reflect on the process and present findings.

4.7 Sustainability of Our Oceans: Plastic / Marine Pollution

Table 4.7

Theme-focused STEM Idea Lesson on Sustainability of Our Oceans: Plastic / Marine Pollution

<table>
<tr><th colspan="3">Sustainability of Our Oceans: Plastic / Marine Pollution</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #14 – Life Below Water (https://sdgs.un.org/goals/goal14)</td></tr>
<tr><td>Unit Objectives Overview</td><td colspan="2">Suggested Learning Experiences</td></tr>
<tr><td>Learning Intentions
• Students will understand the impact of plastic and marine pollution on the ocean and how that affects the Earth and us.
• Students will explore the properties and compositions of plastic and why it is non-biodegradable.
• Students will implement an engineering design process to design a solution that addresses plastic / marine pollution in our oceans (e.g., a seabin).</td><td>Empathising

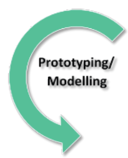
</td><td>• Explore the effects of plastic / marine pollution in our oceans, through a video and a visit to the seaside or marine animal conservation centre.
• Collate data and evidence on ocean pollution, such as photographs and a beach clean-up.
• Analyse the data, for example, sorting the rubbish collected on the beach into different sizes and materials.
• Present findings using information and communications technology.
• Identify the task to help solve the problem. For example, create a seabin that collect a certain type of plastic / marine pollution.</td></tr>
</table>

<table>
<tr><th colspan="3">Sustainability of Our Oceans: Plastic / Marine Pollution</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #14 – Life Below Water
(https://sdgs.un.org/goals/goal14)</td></tr>
<tr><th>Unit Objectives Overview</th><th colspan="2">Suggested Learning Experiences</th></tr>
<tr>
<td>Curriculum Links

Sciences
• Discuss the effects of unfavourable environmental changes and conditions on organisms
• Analyse problems concerning the environment and natural resources in the local area and propose solutions
• List names of organic compounds and their uses.

Technologies
• Use Internet data for the discussion of sustainable development
• Use graphing tool for comparison of the graph and knowing properties of function
• Use projector for sharing ideas such as project survey, reporting and presentation.

Engineering
• Design a product using technology to reduce pollution
• Design products related to the solution of problems associated with the impact of modernisation on the environment</td>
<td>Developing Design Ideas
</td>
<td>• Design a solution to reduce plastic / marine pollution in our ocean.
○ Brainstorm and generate ideas.
○ Research existing solutions and annotate / test if they work in the context.
○ Consider costs, tools, materials, methods and needs of stakeholders.
• Draw some of the possible solutions for creating a sea-bin, and label materials, measurements, and elements of the design.
• Note that the sea-bin design and implementation should not cause more pollution to the ocean, so students need to think of where the seabin will be located and how to sustainably dispose of the rubbish collected.</td>
</tr>
</table>

Sustainability of Our Oceans: Plastic / Marine Pollution		
UN Sustainable Development Goal:	SDG #14 – Life Below Water (https://sdgs.un.org/goals/goal14)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Mathematics • Enjoying problem solving through various questioning for extension of operations into algebra, space and geometry, relationship and functions, and statistics and probability • Using diagrams for exploring possible and various cases logically • Promoting creative and global citizenship for sustainable development of neighbourhood using mathematics	**Prototyping / Modelling** 	• Produce a prototype of the design for your community. • Test and improve each part of the model (minimum three iterations). • Observe, record and explain the effectiveness of the design. • Redesign the product based on findings. • Create a final model of the proposed solution.
	Proposing Solutions 	• Present the final prototype to peers and / or community members for evaluation and feedback. • Respond to feedback, what are the strengths and areas for improvement? • Reflect on the process and present findings.

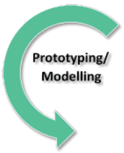
4.8 Clean Water

Table 4.8
Theme-focused STEM Idea Lesson on Clean Water

Clean Water		
UN Sustainable Development Goal:	SDG #6 – Clean Water and Sanitation (https://sdgs.un.org/goals/goal6)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will understand the impact of pollution on the environment. • Students will explore the properties and composition of polluted and clean water. • Students will understand the components and mechanisms of water filtration, including factors affecting liquid pressure, pump, and separation mechanisms. • Students will implement an engineering design process to treat water.	**Empathising** 	• Read articles and watch a documentary on the impact of water pollution on all life on Earth. • Collect evidence such as photographs and news articles on the effect of water pollution in the local community. • Visit local water treatment or management facility and talk to the staff about the issue of access to safe drinking water, sanitation and hygiene. • Discuss the ways of water conservation and water treatment.

<table>
<tr><td colspan="3">Clean Water</td></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG #6 – Clean Water and Sanitation (https://sdgs.un.org/goals/goal6)</td></tr>
<tr><td>Unit Objectives Overview</td><td colspan="2">Suggested Learning Experiences</td></tr>
<tr><td rowspan="2">Curriculum Links

Sciences
Describe the impact of water pollution on the Earth's water resources
Explain the impact of polluted water on animals
Explore and explain ways of water conservation and the preservation of water quality
Perform methods of water purification and preservation of water quality
Technologies
Use Internet data for the discussion of sustainable development
Use graphing tool for comparison of the graph and knowing properties of function
Use projector for sharing ideas such as project survey, reporting and presentation
Explain the technologies behind the water pump, water filters, and water treatment</td><td>Developing Design Ideas

</td><td>Design a prototype water treatment system to produce clean water. The entire water treatment system will need to have a filter and pump.
Brainstorm and generate ideas.
Research existing solutions and annotate / test if they work in context.
Design experiments to investigate the ways to filter and / or treat water.
Consider costs, tools, materials, methods and needs of stakeholders.
Draw some of the possible solutions for water treatment system, and label materials, measurements, and elements of the design.</td></tr>
<tr><td>Prototyping / Modelling

</td><td>Produce a prototype of the design for your home or community.
Test and improve each part of the model (minimum three iterations).
Observe, record and explain the effectiveness of the design.
Creating a final model of proposed solution.</td></tr>
</table>

Clean Water		
UN Sustainable Development Goal:	SDG #6 – Clean Water and Sanitation (https://sdgs.un.org/goals/goal6)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Engineering • Design a product using technology to improve the quality of life • Develop an engineering Habit of Mind **Mathematics** • Appreciate the use of volume in life such as comparison of the capacity of containers • Using diagrams for exploring possible and various cases logically • Enjoying measuring space using calculations with various formulas	**Proposing Solutions** 	• Conduct an exhibition to showcase the prototype to the school and community. • Respond to feedback, what are the strengths and areas for improvement? • Reflect on the process and present findings.

4.9 Water Management and Sanitisation

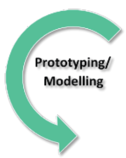
Table 4.9

Theme-focused STEM Idea Lesson on Water Management and Sanitisation

Water Management and Sanitisation		
UN Sustainable Development Goal:	SDG#6 - Clean Water and Sanitization (https://sdgs.un.org/goals/goal6)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Learning Intentions • Students will understand the importance of water management and sanitisation on humans and the environment. • Students will investigate what types of domestic wastewater their household generate (e.g., washing, bathing, food preparation, laundry, sewage). • Students will investigate the local wastewater system through visiting the local sewage treatment facility and / or talking to local authorities. • Students will implement an engineering design process to design a system and improve their home use of water.	**Empathising** 	• Read articles and watch a documentary on the different types of wastewater and the importance of water management and sanitisation. • Visit the local sewage treatment facility and talk to the staff about where household water comes from, where sewage comes from, what is in sewage and how sewage is treated. • Investigate and collect data from their homes about the types of domestic wastewater generated, through taking photographs and talking to their family members.

Water Management and Sanitisation		
UN Sustainable Development Goal:	SDG#6 - Clean Water and Sanitization (https://sdgs.un.org/goals/goal6)	
Unit Objectives Overview	**Suggested Learning Experiences**	
Curriculum Links **Sciences** • Compare the quality of drinking water from different sources • Inculcate the awareness of water and suggest ways of conserving water **Technologies** • Use Internet data for the discussion of sustainable development • Use graphing tool for comparison of the graph and knowing properties of function • Use projector for sharing ideas such as project survey, reporting and presentation	**Developing Design Ideas** 	• Design a water treatment system for their home to improve their home use of water*. This means reusing or recycling water (e.g., water from shower; washing vegetables; rainwater from run-offs; grey water), in a safe and efficient way. Brainstorm any challenges (e.g., mosquitoes breeding in water collector, bad odour, hygiene) to overcome in the water treatment system. ○ Brainstorm and generate ideas. ○ Research existing solutions and annotate / test if they work in context. ○ Consider costs, tools, materials, methods and needs of stakeholders. • Draw some of the possible solutions for water treatment at home, and label materials, measurements, and elements of the design. * A more challenging task is to design a water sanitisation system for the local community, particularly when there is no local water treatment facility.

<table>
<tr><th colspan="3">Water Management and Sanitisation</th></tr>
<tr><td>UN Sustainable Development Goal:</td><td colspan="2">SDG#6 - Clean Water and Sanitization (https://sdgs.un.org/goals/goal6)</td></tr>
<tr><th>Unit Objectives Overview</th><th colspan="2">Suggested Learning Experiences</th></tr>
<tr><td rowspan="2">Engineering
• Design a product using technology to improve the quality of life
• Design products related to the solution of problems associated with the impact of modernization on the environment

Mathematics
• Use mathematics for the minimum and sequential use of resources in situations
• Maximise the use of resources through appropriate arrangement in space</td><td>Prototyping / Modelling

</td><td>• Produce a prototype of the design for your home or community.
• Test and improve each part of the model (minimum three iterations).
• Observe, record and explain the effectiveness of the design.
• Creating a final model of proposed solution.</td></tr>
<tr><td>Proposing Solutions

</td><td>• Conduct an exhibition to showcase the prototype to the school and community.
• Respond to feedback, what are the strengths and areas for improvement?
• Reflect on the process and present findings.</td></tr>
</table>

Below you will find the Iterative Reflection for Design Learning template. This is a reflective activity, designed to be completed by students as part of the Proposing Solutions stage of the PaDL Framework, prior to presenting the final model to stakeholders.

This template can be used to supplement evaluation alongside photographs and observations of student work, and is a self-assessment tool for students to consider their reasoning and what they have learned by completing the design process.

The Iterative *Reflection for Design Learning* is cyclical, with students stating the goal, describing the process, and evaluating each design that they have developed before rebeginning the cycle.

Iterative Reflection for Design Learning

0. State the design goal
   - "My design goal was to…"
   - What is the goal for your first design?

1. Describe the process
   - "To achieve this design goal, I…"
   - What considerations were included in your first design?

2. Evaluate the design
   - "This design was successful / unsuccessful because (how)…"
   - What are the strengths and areas for improvement in this design? What did you learn?

3. Reconstruct the design goal
   - "On my next design, my goal is to…"
   - What is the goal for your second design?

-- rebegin the spiral --

1. Describe the process
   - "To achieve this design goal, I…"
   - What further considerations were included in your second design?

2. Evaluate the design
   - "This design was successful / unsuccessful because (how)…"
   - What are the strengths and areas for improvement in this design? What did you learn?

3. Reconstruct the design goal
   - "On my next design, my goal is to…"
   - What is the goal for your third design?

-- rebegin the spiral –

4.10 Assessment Method

Some assessment methods that you can use to assess students' STEM knowledge and 21st century skills are listed below.

Table 4.10
Some Methods for Assessing STEM Knowledge and 21st Century Skills of Students

Assessment method	Examples
Questionnaires	A student survey to find out their attitudes towards the design learning process, STEM knowledge, confidence, or enjoyment.
Presentations	Students work in groups and each person must present one part of their design learning process. Rubrics can be used for individual and group presentation.
Portfolio	Each group creates a portfolio (physical and / or digital) to show the whole design learning process: brainstorming ideas, drawings of initial designs, build and test prototype, and reflect on their process.
Performance assessment	Each group presents their prototype to the class and / or school and / or community to demonstrate how their prototype address the issue.
Peer assessment	Students assess other groups' designs and presentations, using a rubric or checklist or stickers / likes.
Self-assessment	Students are given a rubric or checklist or a reflection sheet (see the Iterative Reflection for Design Learning) to assess their own learning process and /or their group's prototypes.
Group and individual assessment	The assessment has two parts: one part for the individual and one part for the group.
Technology-based strategies	Students share their design online (digital exhibition), and / or post their reflections in the discussion forum, and / or create a video to show how their prototype works.
Written evidence of the learning process and product	Students write a report or a reflection (see the Iterative Reflection for Design Learning) or complete a worksheet, or a learning journal or letter. They need to show evidence (graphs, tables, diagrams) and their thinking.

Assessment method	Examples
Classroom observations	Teacher observation, checklist, or written notes. The teacher can also take short videos of students' work as evidence for assessment.
Student interviews	Teacher interviews students in groups to find out what they learnt.
Quizzes, tests, homework assignments	The students answer quizzes, tests, or homework assignments on the science, mathematics, technology, and / or engineering knowledge and skills.
Competition	Compare all the prototypes to see which one works best to solve the problem. If the outcome is measurable, it is easy to compare. If not, a group, like the community, can assess the prototypes.
Poster	Students create a poster about their process, showing evidence (e.g., graphs, calculations).

4.11 Sample Rubrics

As you plan your STEM / STEAM units, decide what you want to assess and write down the criteria as shows in Table 4.11. Decide on the rating scale and write descriptions for each level of the rating scale. Things to consider include:

- What science, mathematics, technology, and engineering knowledge and skills do you want to assess? What about 21st Century Skills?
- What assessment method/s are you going to use?
- What might an excellent student product / performance / process look like?
- What might an acceptable student product / performance / process look like?
- What kind of feedback do you want to give students? An overall grade? Detailed feedback for each criterion? Specific feedback to individual and / or group?
- What description do you want to use for the rating scale? (Poor, Below Average, Average, Above Average, Excellent; Approaching / Meeting / Exceeding Expectations; numeric 1, 2, 3, 4)

Table 4.11
Rubric for Assessing STEM / STEAM Plans Using the Design Learning Model

Criteria	**Approaching expectations**	**Meeting expectations**	**Exceeding expectations**
Empathise: Demonstrate empathy and explain the problem / issue	Consider the problem / issue from one or two perspectives or sources.	Consider the problem / issue from the perspective of different stakeholders and sources.	Consider the problem / issue from a variety of perspectives (stakeholders, environment, media, system)
Developing Design Ideas: • Brainstorm • Draw • Link ideas and S,T,E,M knowledge and skills	Brainstorm three or fewer ideas. Draw one idea. Link ideas and science / mathematics / technology / engineering concepts to create one new idea or no idea.	Brainstorm four ideas. Draw and label two or three ideas. Link ideas and S,T,E,M concepts to create two new ideas related to solving the problem.	Brainstorm five or more ideas. Draw and label four or more ideas. Link ideas and S,T,E,M concepts to create three or more new ideas to solve the problem.

Criteria	Approaching expectations	Meeting expectations	Exceeding expectations
Prototyping / Modelling: • Choose ideas to prototype • Choose materials and resources • Build a prototype • Test a prototype • Persevere	Randomly choose one idea to prototype. Randomly choose materials to use. Attempted to build and test prototype but not successful or missing components. Did not refine or rebuild the prototype. Unable to adequately explain the building and testing process.	Adequately explain • which idea/s to prototype, • what materials were used, and • the building and testing process. Build and test the prototype, evaluate the prototype, and refine or rebuild the prototype. Persevere through two cycles of prototyping (choose idea to prototype → consider resources/ constraints → build → test → evaluate → reconsider resources/ constraints → re-build → re-test → re-evaluate)	Systematic and logically explain • which idea/s to prototype, • what materials were used, and • the building and testing process. Build and test the prototype, systematically and analytically evaluate the prototype, and refine or rebuild the prototype based on analysis. Persevere through three or more cycles of prototyping.

Criteria	Approaching expectations	Meeting expectations	Exceeding expectations
Proposing Solution: • Collaborate in a group to combine all the ideas to come up with the "best" solution. • Communicate the solution with others. • Reflect on the entire design process and make improvements. **Reflection** • Consider consequences of solution. • Consider the S,T,E,M knowledge and skills.	Poor attitude during collaboration: negative or withdrawn or disinterested or over-dominating in group discussions. Present information out of order or not in a clear way. Reflection is not clear or systematic or logical or critical. The solution and its consequences are not well thought out. The solution is not connected to S,T,E,M knowledge and skills, or the connections are not well explained.	Neutral or sometimes encouraging and sometimes discouraging. Looks attentive and focused. Give constructive comments. Present information in a clear and well-organised way. Reflection is clear, systematic, logical and analytical. The solution is adequate to solve the problem / issue. The solution is connected to existing S,T,E,M knowledge and skills that students have previously learnt.	Positive attitude during collaboration: supportive, actively listening to others, give constructive comments, and add on to others' ideas. Present information in a clear, systematic, and Convincing way that engages the audience. Clear and systematic reflection that shows higher order thinking, and /or creative and critical thinking. The solution and consequences consider the connections to the community and solve the problem / issue convincingly. The solution is connected to existing and new S,T,E,M knowledge and skills.

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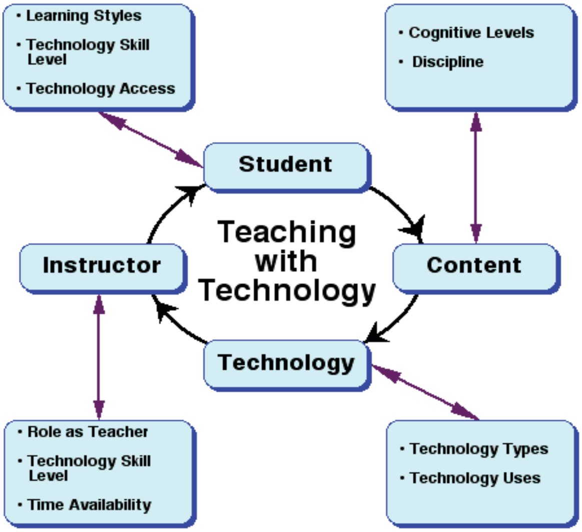
Appendices

Appendix A - Teacher Planning Models

1.



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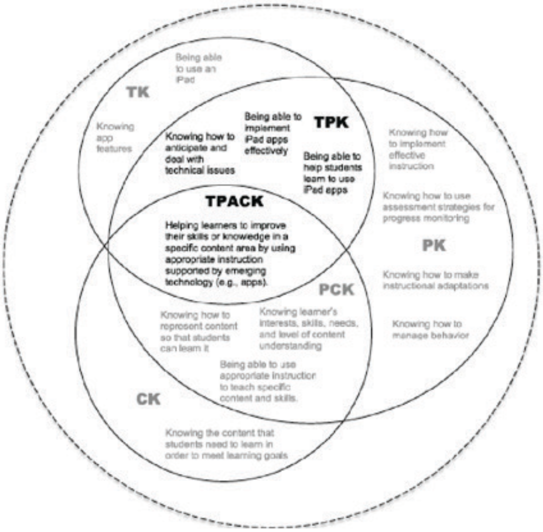
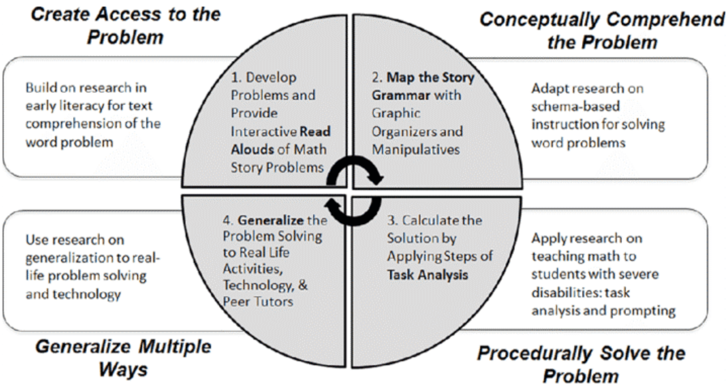
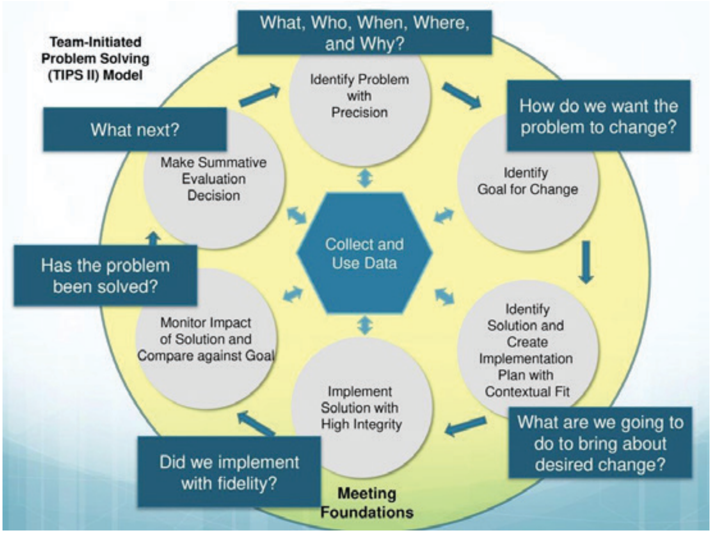


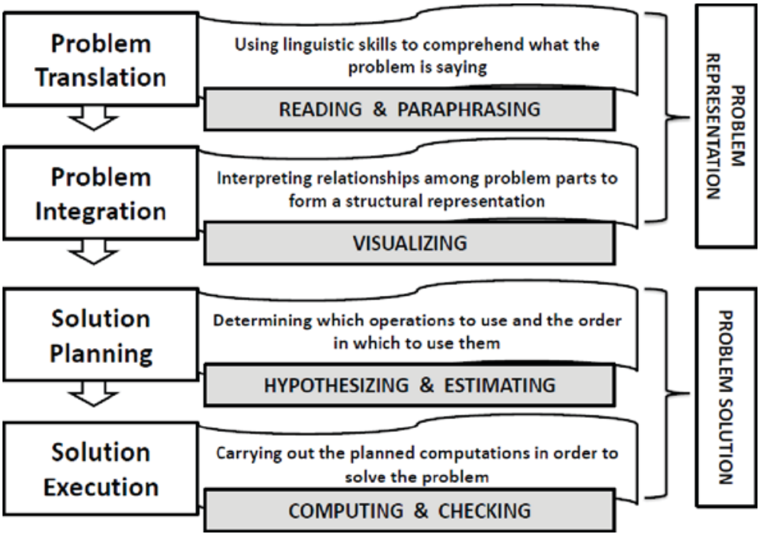
3.


Create Access to the Problem
Build on research in early literacy for text comprehension of the word problem
1. Develop Problems and Provide Interactive Read Alouds of Math Story Problems
Conceptually Comprehend the Problem
2. Map the Story Grammar with Graphic Organizers and Manipulatives
Adapt research on schema-based instruction for solving word problems
Use research on generalization to real-life problem solving and technology
4. Generalize the Problem Solving to Real Life Activities, Technology, & Peer Tutors
3. Calculate the Solution by Applying Steps of Task Analysis
Apply research on teaching math to students with severe disabilities: task analysis and prompting
Generalize Multiple Ways
Procedurally Solve the Problem

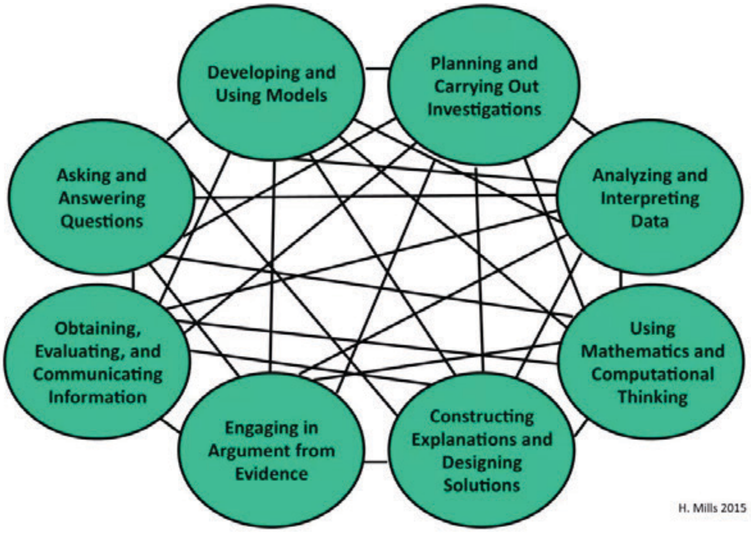
4.


Team-Initiated Problem Solving (TIPS II) Model
What, Who, When, Where, and Why?
Identify Problem with Precision
How do we want the problem to change?
Identify Goal for Change
What next?
Make Summative Evaluation Decision
Collect and Use Data
Has the problem been solved?
Monitor Impact of Solution and Compare against Goal
Identify Solution and Create Implementation Plan with Contextual Fit
Implement Solution with High Integrity
What are we going to do to bring about desired change?
Did we implement with fidelity?
Meeting Foundations

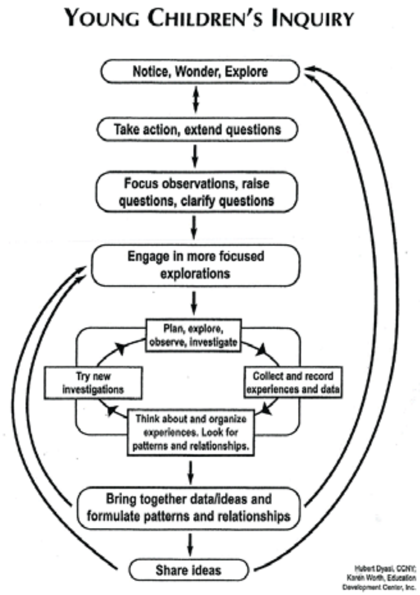
5.


Problem Translation
Using linguistic skills to comprehend what the problem is saying
READING & PARAPHRASING
Problem Integration
Interpreting relationships among problem parts to form a structural representation
VISUALIZING
Solution Planning
Determining which operations to use and the order in which to use them
HYPOTHESIZING & ESTIMATING
Solution Execution
Carrying out the planned computations in order to solve the problem
COMPUTING & CHECKING
PROBLEM REPRESENTATION
PROBLEM SOLUTION

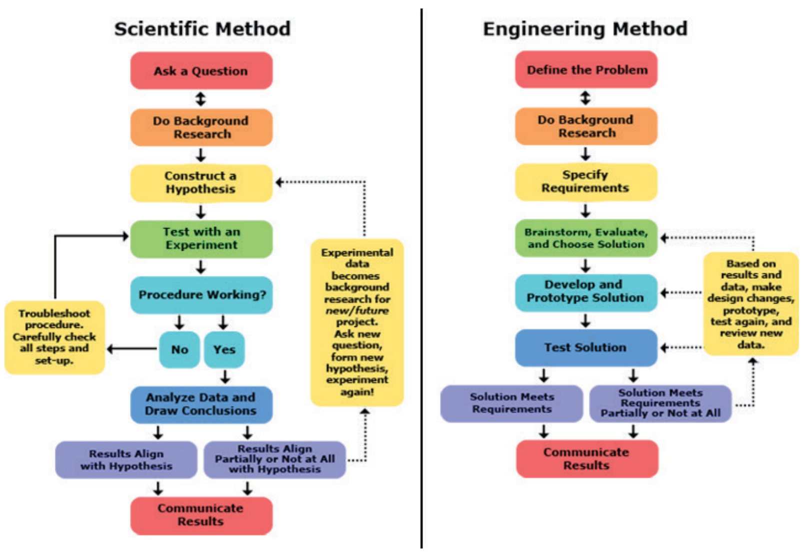
6.


Developing and Using Models
Planning and Carrying Out Investigations
Asking and Answering Questions
Analyzing and Interpreting Data
Obtaining, Evaluating, and Communicating Information
Using Mathematics and Computational Thinking
Engaging in Argument from Evidence
Constructing Explanations and Designing Solutions
H. Mills 2015

7.


YOUNG CHILDREN'S INQUIRY
Notice, Wonder, Explore
Take action, extend questions
Focus observations, raise questions, clarify questions
Engage in more focused explorations
Plan, explore, observe, investigate
Collect and record experiences and data
Think about and organize experiences. Look for patterns and relationships.
Try new investigations
Bring together data/ideas and formulate patterns and relationships
Share ideas
Hubert Dyasi, CCNY; Karen Worth, Education Development Center, Inc.

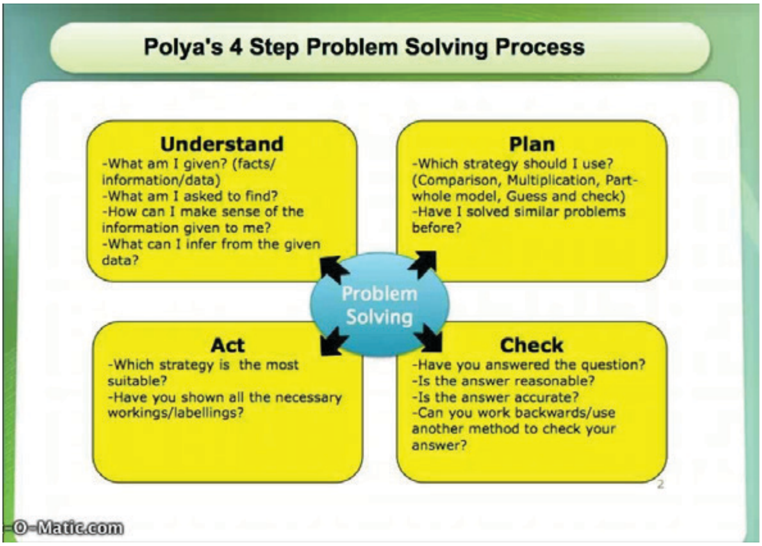
8.


Scientific Method
Ask a Question
Do Background Research
Construct a Hypothesis
Test with an Experiment
Procedure Working?
No
Yes
Troubleshoot procedure. Carefully check all steps and set-up.
Analyze Data and Draw Conclusions
Results Align with Hypothesis
Results Align Partially or Not at All with Hypothesis
Communicate Results
Experimental data becomes background research for new/future project. Ask new question, form new hypothesis, experiment again!
Engineering Method
Define the Problem
Do Background Research
Specify Requirements
Brainstorm, Evaluate, and Choose Solution
Develop and Prototype Solution
Test Solution
Solution Meets Requirements
Solution Meets Requirements Partially or Not at All
Communicate Results
Based on results and data, make design changes, prototype, test again, and review new data.

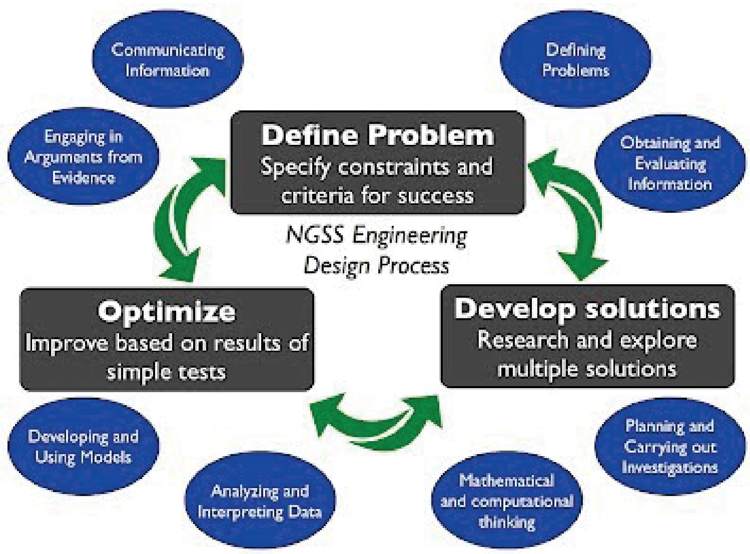
9.

Appendix B - Design Learning for Students Models

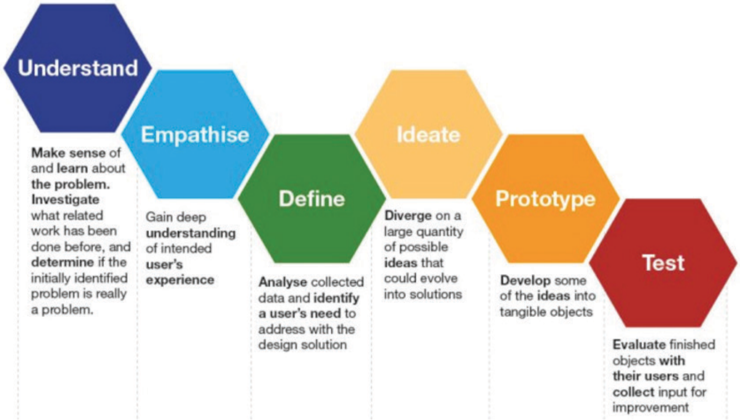
1.



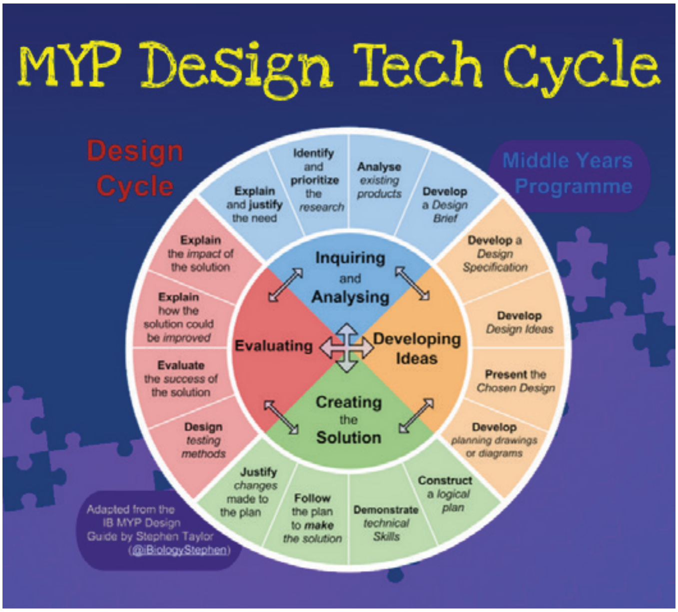
2.


Communicating Information
Defining Problems
Engaging in Arguments from Evidence
Define Problem
Specify constraints and criteria for success
Obtaining and Evaluating Information
NGSS Engineering Design Process
Optimize
Improve based on results of simple tests
Develop solutions
Research and explore multiple solutions
Developing and Using Models
Planning and Carrying out Investigations
Analyzing and Interpreting Data
Mathematical and computational thinking

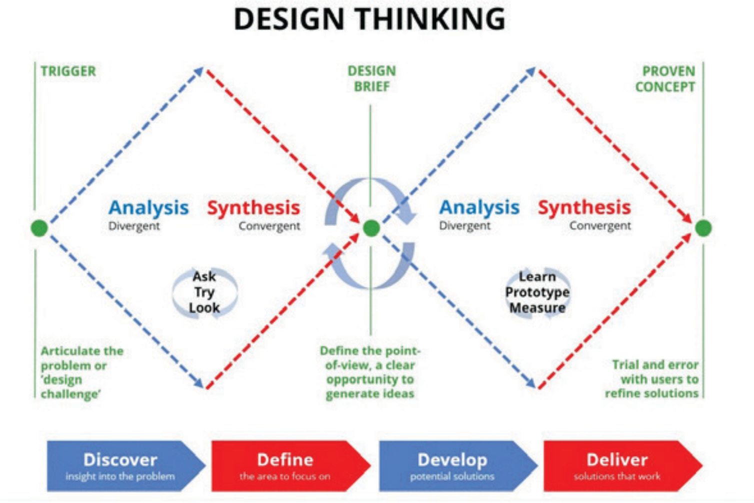
3.


Understand
Make sense of and learn about the problem. Investigate what related work has been done before, and determine if the initially identified problem is really a problem.
Empathise
Gain deep understanding of intended user's experience
Define
Analyse collected data and identify a user's need to address with the design solution
Ideate
Diverge on a large quantity of possible ideas that could evolve into solutions
Prototype
Develop some of the ideas into tangible objects
Test
Evaluate finished objects with their users and collect input for improvement

4.


MYP Design Tech Cycle
Design Cycle
Middle Years Programme
Inquiring and Analysing
Developing Ideas
Creating the Solution
Evaluating
Explain and justify the need
Identify and prioritize the research
Analyse existing products
Develop a Design Brief
Develop a Design Specification
Develop Design Ideas
Present the Chosen Design
Develop planning drawings or diagrams
Construct a logical plan
Demonstrate technical Skills
Follow the plan to make the solution
Justify changes made to the plan
Design testing methods
Evaluate the success of the solution
Explain how the solution could be improved
Explain the impact of the solution
Adapted from the IB MYP Design Guide by Stephen Taylor (@iBiologyStephen)

5.


DESIGN THINKING
TRIGGER
DESIGN BRIEF
PROVEN CONCEPT
Analysis
Divergent
Synthesis
Convergent
Ask
Try
Look
Analysis
Divergent
Synthesis
Convergent
Learn
Prototype
Measure
Articulate the problem or 'design challenge'
Define the point-of-view, a clear opportunity to generate ideas
Trial and error with users to refine solutions
Discover
insight into the problem
Define
the area to focus on
Develop
potential solutions
Deliver
solutions that work

Appendix C - Participants in the in SEA-BES Phase 2 (B) SEA-BES Phase 2 (B) Teaching to Transform: 21st Century Skills and Design Thinking in STEM Contexts Regional Workshop on November 13 – 16, 2018

SEAMEO Representatives	Other Participants	
Brunei Darussalam Hj Noruddin bin Hj Morshidi Shamsulbahri bin Muhammad **Cambodia** Mon Sokha Van Sotheng **Indonesia (QITEP Science)** Dr. Poppy Kamalia Devi Yudi Yanuar **Lao PDR** Koua Xiong Songka Keochansy **Malaysia** Azmi Harun Noraida binti Md Idrus **Myanmar** Daw Nilar Moe Dr. Thin Thin Mar	**Malaysia** Ahmad Syihan Fadzli bin Khairi Grace Wong Chung Wei Hartini Hashim Hidayatul Illah Ahmad Saad Ho Teh Eng Dr. Lay Ah Nam Liew Fook Sin Dr. Marina Ismail Mohd Muzaitulakmam bin Abdul Mutalib Nor'Aidah Nordin Norpizah Binti Hashim Noor Fadzilah binti Aris Norhaslinda bt Jamil Normee bt Abdul Rahman Nuraini Abu Bakar Nurfarahiah binti Amin Badri	**Philippines** Jerico F. Balmes **Thailand** Dr. Lilla Adulyasas Dr. Orawan Thipmani Dr. Pattama Pisapak Dr. Sasithorn Pangsuban **Vietnam** Nguyen Thi Toan Tran Thuy Nga **SEAMEO Secretariat** Mr. Prasert Tepanart **SEAMEO RECSAM** Dr. Chua Kah Heng Mr. Dominador Dizon Mangao Ms. Khor Sim Suan Dr. Ng Khar Thoe Dr. Warabhorn Preechaporn

SEAMEO Representatives	Other Participants	
Philippines	**Malaysia**	**Monash University, Australia**
Bernadeth Daran	Nurul Ain binti Samsuri	AP Dr. Gillian Kidman
Joseph Gutierrez	Radin Muhd Imaduddin bin Radin Abdul Halim	Dr. Hazel Tan
	Dr. Rahayu Binti Johari	Mr. Roland Gesthuizen
Singapore	Ravin Charan Suri	Ms. Simone Macdonald
Cheong Kim Fatt	Rishi Kumar Loganathan	
Ng Chor Yam	Roosaniza Ramli	
	Dr. Ruhizan Mohd Yasin	
Thailand	Salbiah Binti Mohamad Hasim	
Dr. Chotima Nooprick	Siti Nur Diyana Mahmud	
Nopporn Sangatith	Tabitha Boi Chu Chau	
	Tan Suet Li	
Vietnam	Teoh Lydia	
Dao Van Toan	Tuan Raymond	
Do Duc Lan	Wah Mong Weh	

Appendix D - Participants in the 1st Training of Trainers

Name of Participants	**Institution**
Deva Nanthini a/p Sinniah	RECSAM
Wan Noor Adzmin Binti Mohd Sabri	RECSAM
Mariam Binti Othman	RECSAM
Ng Khar Thoe	RECSAM
Nelson a/l Cyril	RECSAM
Loh Su Ling	RECSAM
Muhammad Faiz Bin Abdul Kuthoose	RECSAM
Thiruchelvam Kandaiah	RECSAM

Appendix E - Participants in the 2nd Training of Trainers

Name of Participants	**Institution**
Deva Nanthini a/p Sinniah (Facilitator)	RECSAM
Sharfuddin Bin Abdul Shukor	RECSAM
Wan Mohd Nasir bin Wan Ali	SK Minden Height
Mohammed Falakhuddin bin Haron	SK Minden Height
Sivaranjini Sinniah	RECSAM

Appendix F - SK Minden Height Students

Ahmad Al Addny Awatif Bin Azhar

Ahmad Aliff Sufi Bin Ahmad Ridzuan

Aireen Natrah Binti Azwi

Aleesha Khairina Binti Adelil Fahzuar

Alya Safea Binti Asri

Ariessa Nabihah Binti Khairil Qussairy

Balraj Singh Sidhu

Bushra Binti Mohd Mahadi

Hasselin Aleysha A/P Edison

Jeeveishgautham A/L Pirabaharan
Kamarudeen Siddique Bin Ali Khan
Muhammad Adam Ikhwan Bin Ahmad Nidzam Shah
Muhammad Adam Luqman Bin Muhammad Raziff
Muhammad Afraz Bin Mohamed Azlan
Muhammad Alfateh B Arire
Muhammad Amir Safwan Bin Anuar
Muhammad Amirul Affin Bin Muhammad Rizal Dinakaran
Muhammad Ammar Rayyan Bin Muhd Rizuan
Muhammad Azwar Hasif Bin Mohd Ghazali
Muhammad Danish Arman Bin Zainal Abidin
Muhammad Habil Bin Hasnizal
Muhammad Hafizhan Bin Mohamed Hanif
Muhammad Irfan Nufail Bin Abdullah
Nidhiish A/L Karthikesan
Nur Aleesya Binti Saifullizan Shah
Nur Alleysha Qaisara Binti Muhammad Nuriman
Nur Qaseh Qaisara Binti Mohd Fazly
Nur Raudhah Safiyya Binti Abdul Salim
Nurhannah Irdina Binti Mohd Fazli
Nurul Auni Ardini Binti Mohd Azrul
Ritesh Ramilan
Rittisha Kumaran
Ruhan A/L Saravanan
Shaikh Aiman Atif Bin Shaikh Mohd Hizami
Shakithya A/L Nithya Nanthan
Tusharaa Satrishson
Zeelan Sakthivel Raken

Appendix G - SK Minden Heights School Officials and Teachers

Name of Participants	Position
Fairus binti Ayob	School Principal
Nalina binti Abdul Rahman	Asst. School Principal
Wan Mohd Nasir bin Wan Ali	Technology Teacher
Mohammed Falakhuddin bin Haron	Mathematics Teacher
Suzliza Binti Ismail	Science Teacher

The Project and Authoring Team

Associate Prof. Dominador D. Mangao is currently a Faculty of the College of Flexible Learning and ePNU, Philippine Normal University, Manila, Philippines. He was a former Science Education Specialist at R & D Division, SEAMEO RECSAM. He was the project coordinator of the SEAMEO Basic Education Standards (SEA-BES) which published the *"Common Core Regional Learning Standards in Science and Mathematics"*.

Associate Prof. Dr. Gillian Kidman, Dr. Hazel Tan, Mr. Roland Gesthuizen and Ms. Simone Macdonald are a STEM Education Research team from Monash University, Australia. Together they are working on the transdisciplinary nature of STEM teaching and STEM pedagogies. Gillian's Science based research, teaching and curriculum design is award winning at both the State and National levels in Australia. Hazel, originally from Singapore MOE, has research and teaching interests in secondary mathematics education, educational technology, and international comparative studies. Roland is a STEM Method Lecturer. His current PhD study concerns inspiration and how we teach to inform, and teach to transform in the STEM disciplines. Simone is an Australian teacher. She obtained her Bachelor of Education (Honours) degree at Monash University in 2016. Her particular interest is with the young children and the early learning of STEM. Simone is currently undertaking a PhD on a project relating to STEM Education integration in Early Years and Primary aged children.

Ms. Deva Nanthini Sinniah is a Science Education Specialist at Training and Research Division, SEAMEO RECSAM. She has 13 years of experience teaching at secondary school. She obtained her Master of Education at University Sains Malaysia. Her interest is in Green Chemistry and Science Education. She is the current coordinator of the SEAMEO Basic Education Standards (SEA-BES) and joined the PaDL team at the evaluation stage.

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