CHAPTER 1

Understanding and defining the purpose of STEM

'Tomorrow belongs to those who can hear it coming.'

David Bowie, Heroes

EXAMINING THE UNEXAMINED

As every teacher and school leader understands that when a student walks into a school to learn they arrive with a world of pre-existing knowledge, skills and thinking, as well as a raft of subconscious habits and beliefs. All of these have been formed and internalised over a period of time based on the interactions and experiences they have had (and continue to have) with the people and situations in their lives. Teachers realise that some of the knowledge, skills, thinking, habits and beliefs are consistent with being self-directed learners and thinkers, while some of them are not. Therefore, as part of the teaching and learning process, effective teachers and schools invest the time to find out what students know, what they are able to do, how they think and what beliefs they have about themselves and learning. They then design targeted and differentiated learning experiences and teaching to meet the requirements of the curriculum while nurturing the growth of the human beings in front of them.

Equally, every teacher comes to teach with a range of pre-existing knowledge, skills, thinking and unconscious habits and beliefs. As Judith Lloyd Yero (2010) points out in her research, a teacher's beliefs and thinking about the nature of teaching and learning, about knowledge and about the purpose of education shapes that teacher's practices and can determine which approaches and practices thrive and which cannot be sustained. These beliefs and thinking are made visible through the language teachers use with their students; the way that they plan, deliver and assess the curriculum; the way they set up and structure learning in their classroom; the teaching and learning strategies that they use or don't use; the way they interact and communicate with others; and even the way their organise (or don't organise) themselves (Yero, 2010).

None of this should be a surprise. Of course students and teachers come to the task of learning with pre-existing knowledge, skills, thinking, habits and beliefs! So why do so many schools attempt to design and embed STEM activities and programs without beginning with an examination of the existing knowledge, thinking and beliefs?

Just like a house or a building cannot be built on a shoddy foundation, a sustainable and authentic STEM program cannot be created if schools have not grappled with or explored the pre-existing understandings, thinking and learning structures within the school. What do teachers and school leaders believe STEM learning is? What do students and teachers believe is important to know and understand about science, maths, technology and engineering? What teaching practices and habits do teachers currently have? How do these practices and habits create effective learners and learning? How do these practices and habits relate to effective STEM learning? How do the beliefs and perceptions of students, teachers and school leaders influence the embedding of effective STEM learning structures and approaches? Which teachers, school practices and structures are consistent with a STEM-learning approach, and which are not? Unfortunately, very few teachers or school leaders have the rich collaborative discussions that arise from exploring such questions. This is predominantly why STEM programs fall apart when key people leave. Sustainable STEM programs are built on a shared common understanding of learning and how STEM fits into the school vision and strategic goals.

This chapter supports schools to become clear about their starting point. It begins with two empathising activities that can be used to gain a deeper understanding of what is understood about STEM, the perceived needs that a school is attempting to address, the barriers to enacting STEM in the school and the desired outcomes for STEM and learning at the school. This lays the groundwork for a discussion about one of the major misconceptions about STEM and how the three thinking frameworks within the technologies curriculum can become an empowering context to think from when enacting aspects of STEM and the technologies curriculum. Three key learning concepts are will also be examined to lay the foundation for the thinking throughout this book. The chapter ends with the invitation for a design team to create a shared vision and define a meaningful purpose for an authentic STEM program.

UNDERSTANDING THE EXISTING PERCEPTIONS

It is a fundamental tenet of good design that you cannot design a solution to a challenge or problem without first coming to a deep understanding of the challenge or problem. The creation of an authentic and sustainable STEM program must begin with the process of empathising. In other words:

> *… gain an empathic understanding of the people you're designing for and the problem you are trying to solve. This process involves observing, engaging, and empathising with the people you are designing for in order to understand their experiences and motivations, as well as immersing yourself in their physical environment in order to have a deeper personal understanding of the issues, needs and challenges involved. (Interaction Design Foundation, 2021, 'Empathise' section)*

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Teachers and school leaders can begin to break down existing barriers and walls by examining the current beliefs, practices and assumptions about learning and STEM (as well as their impact). This process will support gaining a deeper understanding of the issues, needs and challenges that will have to be addressed by any STEM program that is proposed. Without having done this work, it is unlikely that any proposed solution will be sustainable. Even worse, the proposed program may perpetuate misconceptions and undermine the transformational possibilities made available by embedding STEM in a school.

The following two exercises are designed to spark a lively discussion within a design team exploring the implementation of STEM learning within a school. The activities encourage participants to voice their concerns, fears and existing understandings so that a shared understanding about the purpose of STEM can be created.

This first exercise begins the process of uncovering the existing perceptions and knowledge around STEM learning. As can be seen from a selection of common responses shown in table 1.1, the responses will begin to capture the experiences, understandings and motivations present in the design team. Some responses demonstrate an incomplete understanding or skewed perception of what STEM is and how it can support school goals. Some indicate a perception that STEM is only about science, technology, engineering and mathematics, or that STEM is an add-on. Other responses highlight that the purpose of STEM is to develop a set of transferable skills (curiosity, problem-solving, critical thinking, collaboration and so on) or about preparing students for the future. Some show an understanding that STEM is transdisciplinary, student-led and can involve learning from mistakes. Across the board, the responses indicate a wondering about how to authentically implement STEM into the current curriculum, teaching and assessment practices.

Exercise: Empathise 1

Form a design team made up of representatives from classroom teachers, middle leaders and senior leadership. If your school culture is particularly transformational, it is worthwhile to also include student and parent representatives. As members of the design team respond to the following questions they should think not only about their own perspectives, but also about those of all students, parents and other teachers of the school.

Reflect on and answer the following questions:

- What are our perceptions of STEM and its purpose?
- What do we understand? What do we not understand?
- Whose needs are we particularly trying to address by enacting a STEM program?
- What are the needs for each of the stakeholders?
- What barriers or challenges are there to enacting STEM in this school?
- What are the current experiences of students and teachers of STEM within this school?
- Are there any other perceptions or concerns in the community we have not yet captured?

Table 1.1 **Sample responses to some of the questions from 'Exercise: Empathise 1'**

Perception of STEM and its purpose	Understandings about STEM	What is not understood about STEM	The needs to be addressed	The barriers or challenges
STEM only involves science and maths	Teachers and students need to be open to make mistakes and willing to try new things	Application – how to do itw	Student social-emotional capabilities	Resistance to change
Problem-based learning (PBL)	It's problem based	How do I implement STEM into literacy?	Students who need to be challenged	Shifting staff perception and thinking
Acronym can vary	Teacher is the facilitator	How does it relate to other curriculum areas?	Addressing the changing world and trying to change our approach based on how the world is going	Time to plan together
Is an add-on to the current curriculum	It is transdisciplinary and student-led	Where intervention can sit	Connecting the learnings across learning areas and one topic to another	Structure of current curriculum planning and teaching practices
Coding is important	STEM leads to entrepreneurial skills, leadership opportunities, new initiatives	How subjects that aren't in the acronym fit into STEM	Engaging and meaningful learning	Timetable
It's got nothing to do with me'	Rich differentiation possibility	How do we manage timetabling and staffing?	Helping students and teachers think conceptually rather than about content	Getting all staff on board
Students will get a positive association with maths and technology	It will create a positive memory for students of their experience	How is this going to impact the current curriculum?	Curiosity	Teachers' confidence to let go of the control and become facilitators
Purpose = to prepare kids for the world beyond traditional education	Will give students a real-world application for maths and science	How are we going to promote this to parents?	Thinking	People will be out of their comfort zones, will be a break in routine
To prepare students to work collaboratively		Best model?	Critical- and creative-thinking skills	Finance, resources, leadership
To support students in problem solving		How to teach the teachers to be facilitators?	Real-world issues	Behavioural issues in students
To make students globally aware		How do we assess some of these skills?	Community problems	Assessment – How? Process?
Filling skill shortage in the industry		How do we know our kids are better in the future because of this?		
Problem-solving				
Critical thinking				
Real-world problems				

Exercise: Empathise 2

Given the responses in 'Exercise: Empathise 1', reflect on and answer the following questions:

- What is the school's current reality around STEM and learning?
- What are the possible causes of it being this way?
- What would be the desired future for STEM and learning?

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The first exercise has the design team thinking and talking about their existing understandings of STEM and paints the broad picture of the issues, needs and challenges. The second exercise digs a little deeper and provides an opportunity for the design team to explore, discuss and think about why things are the way they are and how they would like them to be. This exercise often allows the participants to voice issues, concerns and barriers that were not picked up in the first exercise. It also requires the participants to begin the process of articulating a desirable future that addresses the potential causes of the current reality.

Table 1.2: Sample responses to the questions from 'Exercise: Empathise 2'

Current reality	Possible causes	Desired Future
School is starting to build an integrated approach across curriculum areas Teachers have been discussing and working on differentiation Teachers are hooked on delivering content and the school is hooked on curriculum and systems There is confusion and limited dialogue outside specific curriculum focus areas The STEM acronym is a problem because people can say it has nothing to do with them – it is polarising Some teachers do not know how to start. Do we use PBL? IBL? Perception that only high-performing academic students can do it Fixed perception of the roles of teachers and students There is limited physical as well as timetable space Concern about another tokenistic idea	Lack of transparency across learning areas Lack of time for collaborative team planning? Always done it that way (tradition works) Inconsistent communication because of misinterpretations or biases Traditional assessment and reporting structures Not giving students the permission to make mistakes and learn from attempts Teachers and students not having the freedom to experiment within bounds (lack of trust?)	Distinguish the underlying perceptions and biases that people have, and create a richer point of view Shift the way that teachers and parents think about learning – perhaps re-imagination of schooling Having breaker spaces (break down technology, deconstruction processes in learning areas) and then maker spaces Leadership supporting and trusting teachers through $$, time and structures Collaborative planning embedded in school practice Assessment appropriately aligned to process of learning School identifies themes or concepts that they value at the start and embed in the whole curriculum Teachers collaborating Students collaborating Developing socio-emotional learning and emotional intelligence Drafting and conferencing processes embedded in the way learning occurs in the classroom

The responses shown in table 1.2 demonstrate the range of challenges and barriers schools face when they explore implementing STEM learning. The discussion is important to have because it means the design team considers the necessity of looking at the whole system of teaching and learning, rather than taking a piecemeal approach. How do teachers collaborate to plan learning? Is there a shared common understanding or are teachers accidentally adding to the variance in student understanding? Do the reporting structure and timetable constrain effective learning? Are there misunderstandings, biases or silos of learning occurring? Is there a culture of risk-taking in learning – for teachers and students?

As highlight throughout this book, a well-designed STEM program empowers the agency and leadership of students and teachers. It models and grows thinking, skills and knowledge in a planned manner across the years of schooling. It is consistent with highly effective, evidence-based teaching and learning practices. It challenges the existing systems and processes of learning and demands that schools do the thinking, planning and acting to build a systemic approach to high-quality learning.

THE HIDDEN POWER OF STEM AND THE AUSTRALIAN CURRICULUM: TECHNOLOGIES

A common challenge that is highlighted by the two exercises is the shallow understanding of the purpose of STEM and Australian Curriculum: Technologies. Some teachers and school leaders think it is just yet another thing that they need to put in to an already crowded curriculum. Some people get hooked on the STEM acronym and think that it is only about the disciplines of science, technology, engineering and mathematics. Others argue that we should include A for arts (STEAM) to address creativity and the arts, or H for humanities (SHTEAM) to include the social sciences. Some teachers use the acronym to exclude themselves from thinking about even the possibility of STEM because they believe it doesn't apply to them. As one STEM teacher-leader pointed out to me, one of the biggest barriers she finds when she works with teachers is the mindset that they can't teach new technology or programs because they don't know enough about technology and don't have all the answers they need to teach.

In the Australian Curriculum: Technologies, the two elements (Design and Technologies, and Digital Technologies) both have the aim of using thinking frameworks to generate and produce designed solutions for authentic needs and opportunities. Along the way, students will use 'systems and data; design thinking, systems thinking and computational thinking; and technologies processes and production skills, project management skills, and enterprise skills and innovation; taking into account interactions and impact' (ACARA, n.d.-#, 'Structure: Core concepts' section).

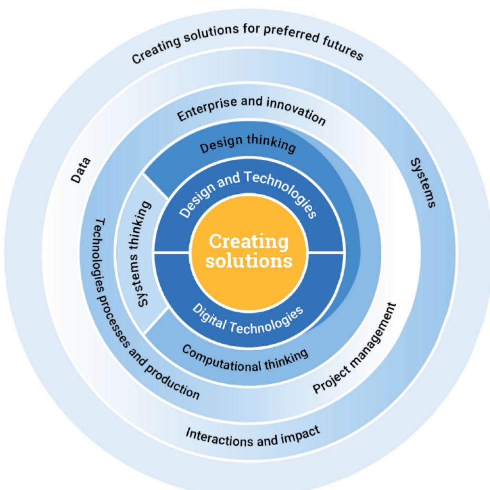

Figure 1.1: ***Overview of the Australian Curriculum: Technologies core concepts***
Source: ACARA (n.d.-#)

The Australian Curriculum: Technologies documentation and videos are quite clear when they describe the intent of the curriculum: the focus is on the thinking first and foremost, and the content is the vehicle for this thinking. This is also true when you examine the curriculum for science, humanities and maths. The true value of the Australian Curriculum: Technologies and STEM are the thinking frameworks and the mindsets that are developed by attempting to create solutions to meet particular needs. If teachers and schools miss this point, they can become trapped by STEM being yet another thing to jam into an already full curriculum. Conversely, if you really grapple with and understand the thinking frameworks underscoring STEM and the Australian Curriculum: Technologies, you may realise that it will transform how learning in schools occurs.

THINKING FRAMEWORKS

Having a framework for thinking provides you with a systematic way of approaching problems and situations that allows you to be effective in creating a solution. This is particularly important when one is learning something new. For example, many English teachers use TEEL (topic sentence, explanation, evidence, link) as a framework to teach students how to write structured paragraphs that link to form an argument. Edward de Bono's (2019) six thinking hats provide a systematic framework of thinking so that by mentally wearing and switching 'hats' you can easily focus or redirect thoughts or the conversation. DIE (diagnose, intervene, evaluate) is a process promoted by John Hattie (2015) when developing teachers to be data informed in their practice. When learning something new, thinking frameworks support the learner to develop clarity of understanding, connect what they are learning to prior knowledge and bring rigour to their thinking.

There are many thinking frameworks present in the Australian Curriculum, though they aren't necessarily described as such. The inquiry skills that are core to science, geography and history can be considered to be thinking frameworks for approaching situations in those disciplines. In mathematics the 'framework of thinking' is described as mathematical reasoning and represents 'an increasingly sophisticated capacity for logical thought and actions, such as analysing, proving, evaluating, explaining, inferring, justifying and generalising' (ACARA, n.d.#, 'Reasoning' section).

The three thinking frameworks at the heart of the Australian Curriculum: Technologies are extraordinarily powerful in that they are useful in all learning. By shifting the focus from the acronym of STEM to the underlying thinking frameworks, a whole new vista opens wherein specific thinking skills and processes can be transferred across multiple disciplines. If teachers and schools start to focus on the skills and processes inherent within each of the three thinking frameworks, every teacher can become a STEM teacher and schools can deliver on their curriculum requirements while developing highly capable learners.

COMPUTATIONAL THINKING

Computational thinking describes the problem-solving processes and approaches to create solutions that can be implemented using digital technologies. When thinking computationally we often draw on approaches such as breaking down problems into parts (decomposition), recognising and interpreting patterns, abstraction, logical reasoning, designing and using algorithms, and creating models to represent processes.

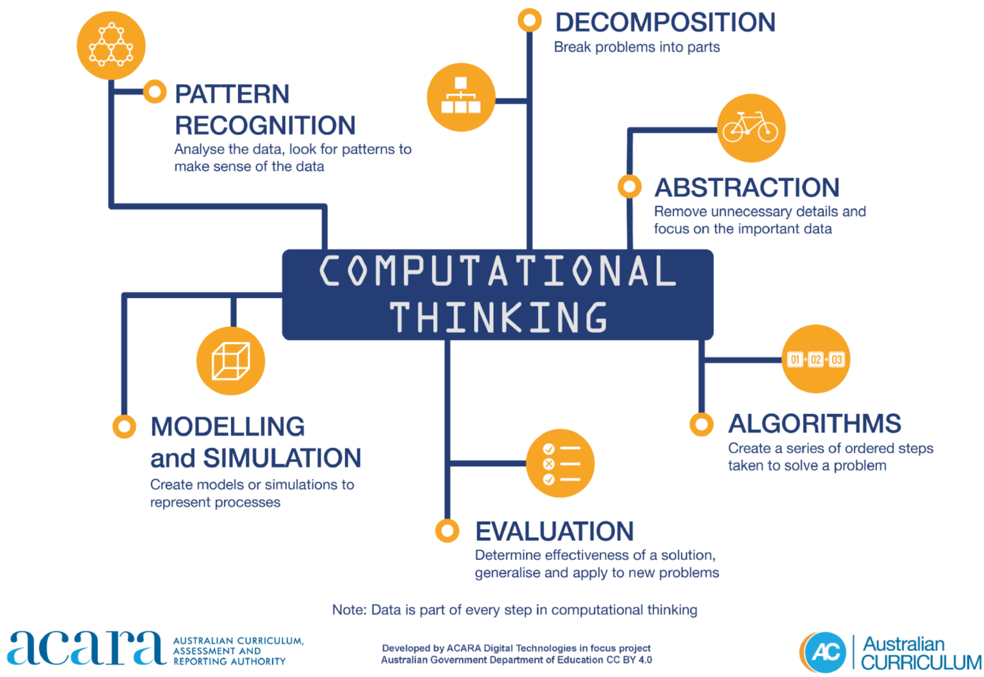

Figure 1.2: **Overview of computational thinking skills and concepts**

Source: ACARA (n.d.-#)

Figure 1.2 is ACARA's brief overview of the skills and concepts related to computational thinking. While the computational thinking framework is an articulation of the skills and concepts that are applicable to digital technology and digital systems, it is not hard to see how they are transferable across other curriculum areas. Building on this, table 1.3 unpacks each of the computational thinking skills into a description of the process, example success criteria, examples of where the skill is used in different disciplines and examples of how it can be used.

Table 1.3: ***Examples of computational thinking skills across disciplines***

Computational thinking skills		
Skill	**Examples of where to use it**	**Examples of how to use it**
Decomposition Decomposition is the process of solving a problem by breaking it down into parts that are easier to solve, understand or manage. **Example can-do statements:** - I can identify why I need to break down a problem/question. - I can identify the parts, essential elements, features of the problem/question. - I can identify parts of a problem that has been broken down into smaller components or stages. - I can break down a problem into smaller parts. - I can use a decision tree to break down a problem and identify requirements and constraints. - I can identify key elements by decomposing the problem.	**Digital technologies:** - We can break down a complex problem or system into smaller parts that are more manageable and easier to understand. The smaller parts can then be examined and solved or designed individually as they are simpler to work with. **English and the arts:** - Deconstruction is an approach to breaking down something (sentence/paragraph/text) into its separate parts to understand its meaning. - Identifying the key words and ideas in a text is the first step to being able to infer and attribute meaning. - Analysis is built on the skill of deconstruction. - To create an interactive story, one can decompose the problem to a list of characters and their characteristics, the actions of the characters, the backdrops and the sequence of scenes with reference to which characters, actions and backdrops are involved in each scene. - Genres in English can be distinguished between based on the way students decompose them. For example, the structure of poetry is different from the structure of a report; metre and rhyme are not relevant in the report genre, just as logical structure is not necessarily relevant in a poem. **Mathematics:** - Teaching learners how to deconstruct a worded problem using strategies, such as identifying the key words and creating a diagrammatic representation of the problem, is the first step in being able to apply the appropriate strategy to solve the problem. - Decomposition may be represented in diagrams.	When something seems complex, the first step is to see if you can break it down into smaller parts. Let's decompose the problem into smaller parts. Let's deconstruct that sentence/paragraph to understand its meaning. Let's deconstruct that, identifying the key words and ideas. Let's deconstruct that by drawing what the question is asking. Let's decompose the question by identifying the independent and dependent variables. We will now use the skill of decomposition to break down the problem into more manageable/understandable parts. Problem-solving is puzzle solving. Each smaller problem is a smaller piece of the puzzle to find and solve. To solve the question/text/problem we need to decompose it into smaller parts. What are the pieces of your puzzle? How are you going to find them? Are these easier to solve?

Skill	Examples of where to use it	Examples of how to use it
	Science: ▪ The process of identifying the independent and dependent variables so one can pose a hypothesis and design a valid test is a process of decomposition.	
Pattern recognition Pattern recognition is the process of finding patterns and order in information, and looking for similarities among and within problems so you can analyse, interpret and communicate it. **Example can do statements** ▪ I can identify ... ▪ I can compare ... ▪ I can contrast ... ▪ I can sort and classify .... ▪ I can sort data into groups and describe each group type. ▪ I can organise the data so I can make sense of the data. ▪ I can describe patterns in the data. ▪ I can represent data in different ways using symbols and images. ▪ I can sort data into groups and describe each group type. I can organise the data so I can make sense of the data. ▪ I can describe patterns in the data. ▪ I can represent data in different ways using symbols and images. ▪ I can identify features and characteristics of books that allow for them to be sorted. ▪ I can sort and organise data and identify patterns in data. ▪ I can accurately organise data in spreadsheet software and can use that data to generate a graph.	**Science and geography:** ▪ Looking for patterns in data and observations helps to make predictions and identify cause and effect. **History:** ▪ Recognising patterns in societies and cultures allows the analysis and interpretation of societal trends. We make sense of our world by looking for patterns.. **Mathematics:** ▪ Pattern recognition is core to mathematics and the fields of probability, statistics and number. There are patterns in the times tables. Patterns in recognising shapes **English:** ▪ There are patterns in the similarities and differences to the sounds of letters and words. ▪ Pattern recognition is used when students are connecting read words to pictures. ▪ Compare and contrast is a pattern finding approach. **The arts:** ▪ Patterns are absolutely everywhere – colour, drawing, concepts etc. **Science:** ▪ Observation is all about pattern recognition. ▪ Dichotomous keys are based on pattern recognition.	What are the patterns here? How can we use the patterns or organise the information? How is this problem similar to that problem? What are the similarities and differences here?How can we use the patterns to sort the ...? If that is the pattern how can we use it to interpret the ...? How can we use the patterns to sort the ...? When you can recognise the patterns in the information/data, it helps you to analyse and interpret what is going on.

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Abstraction Abstraction is the process of filtering out or ignoring details that are not relevant or that we don't need in order to concentrate on information that is important or needed so that a solution can be developed. **Example can-do statements:** - I can point out the details of ... - I can identify what is important and what is not. - I can identify what is relevant to a topic and what is not. - I can use the patterns in the data/information to classify it. - I can simplify the information into categories. - I can identify the main ideas. - I can explain why something is important or not. - I can justify why something is important or not.	**Design and technologies:** - The define phase of the design thinking process involves not only looking for patterns in all the information gathered but getting clear about what is important and what is not so that the designer can narrow the focus for designing a solution. **Science:** - The careful and creative use of abstraction is core to forming theories. Einstein's theory of relativity, for example, was built on filtering out what he felt was not important and concentrating on certain characteristics of the patterns he saw. - Occam's razor is a principle that suggests that if two explanations exist for an occurrence the one that requires the smallest number of assumptions is usually correct. **The arts:** - Abstract art does not attempt to represent an accurate depiction of a visual reality but instead use shapes, colours, forms and gestural marks to represent and communicate specific ideas and characteristics to a viewer. **English:** - The art of persuasion, argument and debate is built on the skill of abstraction. **Mathematics:** - Abstraction helps us understand the idea that a cricket ball is a sphere in the same way that a soccer ball is. - Data can be organised in records made up of fields irrespective of whether the data are numbers, text, images or something else.	When we read the text, what are the key words? What is the important information in the question? Can you draw what the question is asking? What information is relevant/important here? What information is not relevant/important here? What should we concentrate on? Now that we have identified the patterns, what should we focus on? How can we simplify the information so we can decide what to focus on? Can you explain why that is relevant/important? Can you justify why that is relevant/important?

Continued ...

Skill	Examples of where to use it	Examples of how to use it
Algorithms Algorithms use a series of ordered steps to solve a problem or complete a task. **Example can-do statements:** ▪ I can identify and follow a series of steps to complete a task. ▪ I can follow a sequence of steps to solve a problem. ▪ I can describe the steps of an algorithm for a task. ▪ I can define an algorithm as a series of steps. ▪ I can create a flowchart for an algorithm. ▪ I can follow an algorithm. ▪ I can describe an algorithm and what each part means. ▪ I can describe an algorithm for a familiar task. ▪ I can explain how to create an algorithm for a simple task. ▪ I can create an algorithm and identify where user input results in possible different actions. ▪ I can explain how to improve an algorithm. ▪ I can seek feedback to improve an algorithm. ▪ I can order steps in the right sequence if I'm given the steps of the task. ▪ I can identify parts of the algorithm where choices are made (branching) and different events or actions result from user input.	**Health and PE:** ▪ Health and PE are replete with tasks that have steps that need to be done in a particular order (algorithms). ▪ Most recipes follow a series of steps to make a particular dish, dance steps follow a choreography timed to music, even sport activities such as kicking a ball or throwing a ball can be broken down into a sequence of steps. This enables learwners to understand how to complete a particular task and can be used to coach them to be more effective. **General capabilities:** ▪ Unconscious algorithms exist in the automatic things that we all do in the mornings such as the steps to get ready for school, steps to brush our teeth, steps to be ready to learn in class, even planning to achieve a goal. ▪ These can be highlighted as forms of algorithms and be used to coach students on developing themselves in the capabilities **English:** ▪ Routines such as TEEL to write persuasive essays are algorithms. ▪ Teachers can examine similar routines and begin to language them as algorithms. **Mathematics:** ▪ Procedures in mathematics are algorithms (e.g. the method one uses to solve long or short division). One could even flowchart a mathematical procedure to make it visible to the students. **Digital technologies:** ▪ Apart from programming, the steps a computer goes through to boot up can be considered an algorithm. ▪ Having students create flowcharts showing the flow of the steps, any branching and any iteration is a great visualisation tool for algorithms	What is the sequence of steps of …? What are the steps you take to get ready for school? Describe the steps you took to solve that. Can we make an algorithm for doing that task? Can you follow that algorithm? Please follow the algorithm we put up for writing the essay. What are the decision points in the IF–THEN algorithm?

Modelling/simulation Modelling/simulation is creating a model that represents the operation of a process or a system to gain insight on the workings, structure and relationships within an object, system or idea so that predictions can be made. **Example can-do statements:** ▪ I can create a model of a process. I can create a model of a digital system and explain the parts and software it uses. ▪ I can use data to model an object or event. ▪ I can design a prototype model of a real-life solution. ▪ I can create a paper prototype of my design to show how it will work. ▪ I can create a storyboard of a story to predict the flow of a story. ▪ I can annotate a sequence explain how a prototype meets user needs. ▪ I can discuss the relationship between a model and the real-world system it represents.	**English:** ▪ Prior to students writing a story, they can create a story board which models the flow of the story with the relationships between different incidents and characters. This will enable them to have a more coherent picture of the story as they write it. **Mathematics:** ▪ Mathematical models are. used constantly to represent real-life data and systems. This includes fitting trend lines to data and using mathematical models to represent collated real-life data **Science:** ▪ Models are used to represent particular real-world phenomena that aren't necessarily visible (e.g. cells, atoms). This allows scientists to create hypotheses and design theories. ▪ Scientists also use data from a simulation or a simplified model to make a prediction (e.g. climate change). **Design and technologies:** ▪ During the design process it is normal to create a drawing of the product or system during the ideation process. The drawings then become more detailed and can even be annotated to explain particular features. This allows a more accurate prototype or model to be built before creating a full-sized version. They are low-cost simulations designed that allow fast problem solving and evaluation of the concepts.	How can we simulate that so we can understand how it could work? How can we model that? What is a simplified version of that? Before we write the story, we can create a storyboard (or model) of the flow of the story. Models are used to give us insight into how things work. Can we use the model to make a prediction? Can we use the model to explain how it works? Designers make prototypes to test a process or concept. They can then evaluate a new design quickly and cheaply.

Continued ...

Skill	Examples of where to use it	Examples of how to use it
Evaluation Evaluation is the process of examining and judging the merit, significance or value of something to determine its effectiveness in meeting criteria. **Example can-do statements:** - I can use criteria to evaluate my ideas. - I can evaluate the effectiveness of … - I can determine the purpose and criteria for this evaluation. - I can examine the ideas, works, solutions and/or methods. - I can determine the merit, value or significance of the ideas, works, solutions or methods. - I can appraise the strengths, limitations, implications in relation to the selected criteria. - I can review the evaluation to ensure the criteria have been applied and the reason for this evaluation has been met. - I can evaluate the usefulness of the published information or product against agreed criteria. - I can evaluate a game and describe its usefulness.	**Design and technologies:** - The process of evaluating ideas and design concepts against set criteria is part of the improvement cycle in design and is fundamental to creating products that meet articulated needs. **General capabilities:** - The process of evaluation is core to developing self-regulated learners. For example, they could evaluate their behaviour against a norm or agreement to ensure they are operating as a team. Equally, they could compare their work against a rubric or existing piece of work to improve the quality of what they are expected to deliver. **English and languages:** - Persuasive writing involves evaluating information to draw conclusions and justify opinions. It is a key skill required to be a critical thinker and writer. **HASS and science:** - Evaluating evidence is critical to forming and assessing hypotheses. Evaluation is part of the inquiry skills in these disciplines. **Mathematics:** - Once a student has arrived at a solution it is important for them to evaluate the reasonableness of the solution. They need to ask questions such as: Does it make sense? Is it approximately what they thought it should be? This ensures they have not made a mistake in their calculations.	Evaluate is a key cognitive verb used throughout the curriculum in many contexts. We can begin the process of evaluating by coming up with a set of criteria. How could we judge the merit of that idea? How will we know if we are effective? We can evaluate … What can we do to assist in evaluating the impact of recent changes? How would we evaluate the results of the experiment? What is the significance of …? How do you know it is valuable? We first have to have some criteria to judge the value of X and then evaluate against that criteria.

Teachers can begin to develop student understanding and use of the skills and concepts inherent in computational thinking by using the language and strategies in all learning areas. As will be pointed out later in this chapter and in Chapter 5, deep learning and the ability to transfer learning to new situations is enhanced when students internalise the language and usage of learning strategies across multiple learning areas.

DESIGN THINKING

Design thinking is embedded in both the Digital Technologies and Design and Technologies Curriculums. It is an iterative and non-linear process used to solve complex problems and find useful

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solutions. As the Australian Curriculum articulates, design thinking 'helps people to empathise and understand needs, opportunities and problems; generate, iterate and represent innovative, user-centred ideas; and analyse and evaluate those ideas' (ACARA, n.d.#, 'Structure: Design thinking' section).

When introducing the design thinking process to schools I prefer to use the Stanford d.school model (see a variation on this model in figure 1.3) as it is easier to explain to teachers and students in comparison to the descriptors used in the Australian Curriculum. Table 1.4 shows the relationships between the d.school model and the Australian Curriculum processes and production skills.

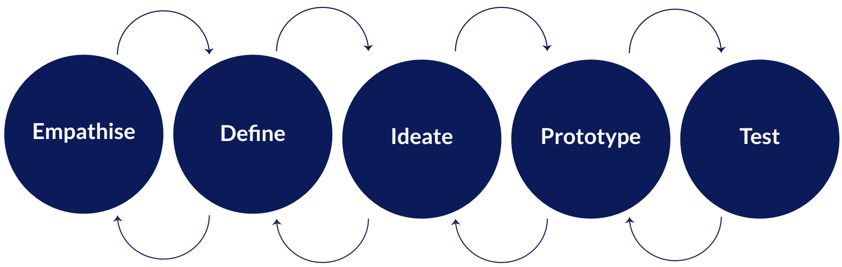

Figure 1.3: ***Variation on the design thinking model***

Source: Adapted from Hasso-Plattner Institute of Design (2020)

Table 1.4: ***Relationships between the Stanford d.school model of design thinking and the Australian Curriculum Processes and Production skills***

Stanford d.school model of design thinking	Australian Curriculum processes and production skills	Across the design process
Empathy	Investigating	Collaborating and managing
Define	Defining	
Ideate	Generating and designing	
Prototype	Producing and implementing	
Test	Evaluating	

Source: Adapted from Hasso-Plattner Institute of Design (2020) and ACARA (n.d.#)

The skills inherent in the design thinking process, much like in computational thinking, are transferable and applicable in many disciplines. Table 1.5 unpacks each of the design thinking skills into a description of the process, example success criteria, examples of where the skill is used in different disciplines and examples of how it can be used.

Table 1.5: Use of design thinking skills across disciplines

Design thinking skills		
Skill	**Examples of where to use it**	**Examples of how to use it**
Empathising Empathising is the process of identifying goals and sub-goals, giving up assumptions, gathering information and data, and putting yourself in the shoes of the user to come to a deep understanding of a challenge and who you are designing for. This stage involves a significant amount of divergent thinking as it is an analysis process – the process of breaking down complex concepts and problems into smaller, easier-to-understand parts. It requires the learner to give up their pre-conceived notions and assumptions and be open-minded as they gather information and data. The computational thinking strategy of decomposition is particularly useful for empathising as it allows students to identify the elements of a task so they can seek information to understand. **Example can-do statements:** - I can identify ... - I can describe ... - I can use clues to ... - I can locate ... - I can identify and describe the parts of ... - I can define a problem and break it into smaller parts. - I can gather information. - I can collect/record data. - I can identify the key words, ideas or concepts. - I can identify the needs of the user. - I can describe the pros and cons of ... - I can describe different points of views.	**English:** - Empathising is a key skill of the literacy strand. - When you read a text you are looking for clues and information, within the text and outside the text, so you can gain an insight into the possible context for the actions and behaviours of the characters or the ideas and concepts being discussed. - Identifying key words, concepts and ideas leads to understanding. - The more skilled a learner is in empathising, the better they are at coming to a deep understanding of what is written and inferring from what is written. **Other disciplines:** - The more skilled a learner is in empathising, the deeper they will understand the situation and how to communicate it. - Experimentation in science and art is about empathising and looking for data/information so that patterns can be recognised. - Watching/reading about other people's perspectives is an empathising process. - Identifying key words and drawing the situation leads to clarity in maths – particularly worded problems.	If we are to empathise with users, we should always try to adopt the mindset of a beginner. What are we observing? What are the assumptions here? What is the key information we are looking for? Photographing or recording target users can help you uncover needs that people may or may not be aware they have. How can we come to a deeper understanding of the situation? What are the clues in the picture or text? What are the needs of the person/group/user? Why did they behave that way? If that was you, what would you do? How could we find out what they need? What did you learn from making the prototype? What are the parts of the problem? What might a computer do? Ask lots of 'what if' questions.

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Defining

Defining is the process of synthesising the information that was created during the empathise stage for the purpose of looking for patterns and gaining insight to articulate what to focus on or the problem that will be solved.

This stage involves a significant amount of convergent thinking as it is a synthesis process (creatively piecing together the puzzle together to form whole ideas) with the aim of clearly articulating what to focus on or the problem to be solved.

The computational thinking strategies of abstraction and pattern recognition are particularly useful in this stage as the learner identifies what is important and what is not amongst the information gathered.

Example can-do statements:

- I can sort and classify ...
- I can compare and contrast ...
- I can arrange ...
- I can organise data and information.
- I can represent the data in different ways for different purposes.
- I can create charts and use other ways to visualise the data to help make sense of patterns and trends.
- I can identify what is relevant to a topic and what is not.
- I can make generalisations based on the data I have collected, organised, sorted and analysed.

The skill of defining what to focus on is a core learning skill in multiple disciplines. It requires the learner to develop the capacity to be clear about what is being asked of them so they can then apply the appropriate strategy.

Mathematics:

- Teachers know that students can find worded problems much more difficult than when they are given a formula to solve. By developing their capacity to distinguish what is important and what is not in worded problems (a synthesising process), they will become better and choosing the most appropriate strategy.

English and HASS:

- The skill of inferring requires students to synthesise information from the text so they can understand or predict character or scene. This requires students to look for patterns and make meaning from what was written.
- I can identify the needs and wants of the end users.
- I can create a mind map to show relationships between information.
- I can sort and organise data and identify patterns in data.
- I can organise data and use that data to generate a graph.
- I can identify what is important and what is not

Science:

- Scientists find patterns and synthesise the data they have gathered so they can make predictions (hypotheses) about future outcomes. This enables them to focus experimentations on particular variables and exclude others.

Health and PE:

- Coaches in sport and dance synthesise information gathered from observations to identify what to coach someone on as they develop a skill. This can lead to the development of specific drills to build a skill.

Let's look at all the information we have gathered and see if we can find some patterns.

What does the picture tell us about what the author wrote?

What problem is the character in the story trying to solve?

Let's work on defining what problem the character is attempting to solve from the clues in the text.

Now that we have identified the key words and ideas what is the problem we are trying to solve?

We are in a define phase in solving this problem:

- What patterns can we see?
- What is important and what is not?
- What should we focus on?

The:

- [user . . . (descriptive)] needs
- [need . . . (verb)] because
- [insight. . . (compelling)]

How might we:

- make TV more social, so youths feel more engaged?
- enable TV programs to be watched anywhere, at any time?
- make watching TV at home more exciting?

Continued ...

Skill	Examples of where to use it	Examples of how to use it
Ideation Ideation is the process of generating a large quantity of ideas and filtering down the ideas into the best, most practical or most innovative ones to inspire new and better design solutions and products. This stage is about creativity and divergent thinking. It has the learner start to think outside the box, look for alternative ways to view the problem and identify innovative solutions to the problem statement they've created. Many possible solutions are explored in a short amount of time and unexpected connections can be drawn. There is no evaluation during this stage as that would shut down the divergent thinking. **Example can-do statements:** - I can draw/sketch various possible solutions to a problem. - I can identify various strategies that I could use to solve a problem. - I can annotate my sketches design to clarify the pros and cons of each. - I can compare and contrast features of existing products to provide new ideas. - I can describe how a design idea meet the needs of those who will use the solution. - I can use a variety of critical and creative thinking strategies (eg. brainstorming, sketching, 3D modelling and experimenting) to generate innovative design ideas.	In ideation sessions, it's important to create the right type of environment to help create a culture with a curious, courageous, and concentrated atmosphere. All judgement is deferred (there are no stupid ideas). In fact one must encourage weird, wild and wacky ideas. Teachers can use this process pedagogically in many day to day situations. However, students need to be explicitly taught: - different strategies to generate new ideas without judgement - strategies to collect, categorise, refine and narrow the ideas. **Science:** - Having students brainstorm potential outcomes of an experiment is creative practice. These predictions can be discussed and refined as they gather more information from experiments. **English and HASS:** - Building on the skill of inferring (see the 'Defining' row in this table, p. ##) students can then explain the motivation of a character in a narrative or a historical setting. This will deepen their ability to use figurative language such as allegories, similes, analogies, metaphors and more. **Digital and design technologies:** - Brainstorming the features of a game or a product that meet a range of design criteria is an example of ideation. Students can explore a wide range of options and make new innovative connections as they formulate a potential solution.	What are some weird and wacky ideas to solve this problem? Draw at least five ideas that solve … What are some adjectives that could describe the situation/character? What are the pros and cons of each idea? Let's come up with as many ideas as we can. Fill in a PMI (plus, minus, interesting) template for each of your ideas. What are features we see elsewhere that could be useful here? Let's brainstorm possible ideas and solutions to this situation. What are some of the best features of the ideas we have seen? What is another way we can look at this problem that might give us some more ideas? How does each idea meet the needs of the users?

Prototype–test–evaluation iterative cycle The iterative cycle is a process of creating a model, simulation or scaled down prototype of the product; evaluating how well the product meets expectations, wants and needs; and providing feedback to refine/improve the model, simulation or scaled down prototype with the aim of identifying the best possible solution using minimal time and effort. These stages involve a convergent thinking process where the various ideas generated in the previous stage are put together in some organised, structured way and feedback is used to refine and improve the product. Note: Sometimes the learner discovers they need to return to an earlier stage as the prototyping and testing can reveal new problems, new ideas and new solutions. **Example can-do statements** • I can create ... • I can evaluate ... • I can refine ... • I can use feedback to ... • I can build models or representations (prototypes) of ... • I can repeatedly test the prototypes and use the results to continually inform improvements to ... • I can create a chart/graph and discuss its usefulness. • I can collaborate to create and refine a product. • I can create a program for a particular purpose and evaluate its effectiveness. • I can evaluate the appropriateness of my own behaviour and conduct. • I can seek and act on feedback.	The iterative process is one where students use formative feedback from self, peers and teachers to incrementally learn or improve. Teachers will need to explicitly teach the processes of: • building a model, creating a draft and having a go at skills • reflecting on how well an attempt meets the expectations, criteria and desired outcome • using feedback to identify actions/ strategies to improve outcomes. **English and HASS:** • When writing, writers go through a drafting process. This process often involves multiple iterations of drafting text, reading it and evaluating it against criteria such as coherency and whether it fulfils its intention. Authors can even receive feedback from editors and readers to improve the quality of the written piece. **Science:** • The process of designing an effective science experiment to test a hypothesis involves multiple iterations. This iterative cycle ensures that the test is fair and valid. **General capabilities:** • Learning involves the progressive development of a set of skills. Skills such as critical and creative thinking, collaboration, and self-regulation require learners to practice, receive feedback and refine their strategies and behaviour. This iterative process mimics the prototype–test–evaluation iterative cycle. **Health and PE, and the arts:** • Development of a skill in physical disciplines such as sport, art, cooking and so on follow the iterative cycles of practising, receiving and using feedback, and then refining one's strategies.	Does the product meet the needs and wants we originally identified? Now that we have tested the design, in what ways could it be improved? How well does our prototype meet the design criteria? What feedback would you give one another to improve your draft? How could we use the rubric to improve our solution as we go through the iterative cycle?

The design thinking process is applicable in many learning areas. Using the language of the design process across the learning areas will allow for transferability of skills and thinking. For example, students will begin reading a text (and perhaps looking at the associated images) and will go through the empathising stage as they come to an understanding of what the author is describing or arguing. From discussions with each other and the teacher, plus any prior knowledge, they will recognise any patterns and identify the key words and ideas (define stage). The teacher may then pose a question, prompting the students to brainstorm possible answers (ideate stage). The teacher may then direct students to practice writing a response and refine their writing skill via a drafting process with formative feedback (prototype–test–evaluate iterative cycle).

SYSTEMS THINKING

Much like design thinking, systems thinking is embedded in both the digital technologies and design and technologies curriculums. Systems are made up of a set of components that work together in a particular environment to achieve the overall objective of the whole. Systems can have sub-systems and may themselves be part of larger systems.

Systems thinking is the process of identifying and examining the interactions between different components (or sub-systems) of a system to understand how the components influence each other and the function of the entire system. In nature, ecosystems are an example of a system in which various elements such as air, water, movement, plants and animals work together to survive. Schools, classes, societies, landscapes, food webs, team sports and the human body can all be considered examples of systems.

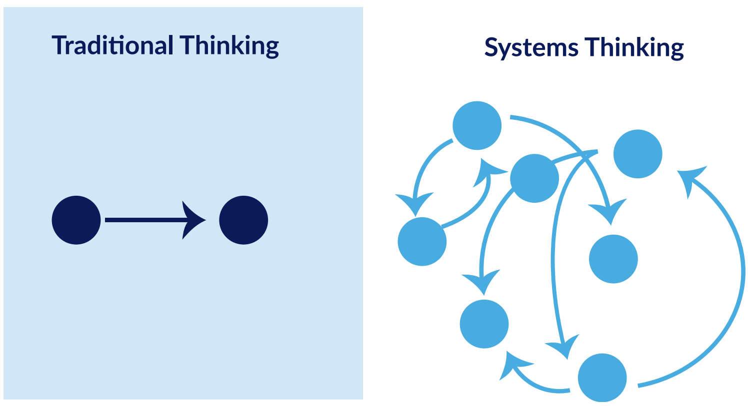

Figure 1.4: Traditional and systems thinking

Systems thinking is distinct from design thinking and is often associated with analysis – the process of breaking something down into its component parts to understand it. As the Australian Curriculum highlights, systems thinking 'helps people to think holistically about the interactions and interconnections that shape the behaviour of systems' (ACARA, n.d.#, 'Structure: Systems thinking' section). Design thinking is more associated with the process of synthesis – using the understanding gained through analysis to create a solution. Table 1.6 unpacks systems thinking into a description of the process, example success criteria, examples of where the skill is used in different disciplines and examples of how it can be used.

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Table 1.6: ***Use of system thinking across disciplines***

System thinking skills		
Skill	**Examples of where to use it**	**Examples of how you can use it**
Systems thinking Systems thinking is the process of identifying the different components (or sub-systems) of a system and identifying and examining the interactions between these components to understand how the components influence each other and the function of the entire system. **Example can-do statements:** • I can produce a diagram that shows the interactions between different parts of a system. • I can create a flowchart of an algorithm. • I can identify the interactions between parts of the … • I can explain how and why … behaves as it does. • I can test and evaluate a prototype to understand how each part influences the others. • I can discuss the constraints on the solution/system. • I can compare the similarities and differences between two similar products/systems to help predict the function/purpose of each part. • I can identify patterns of behaviour over time. • I can identify possible causes of a problem.	**English:** • Systems thinking is demonstrated by learners understanding how different language usage produces different effects and even how different text structures have different purposes. • Filmic analysis requires learners to examine the interactions between components such as lighting, music and camera angles and how they influence the viewer's perception. **The arts:** • The analysis of art involves an understanding not only of the specific techniques used by the artist but also of trends and thinking at the time of production. An artist is not separated from the 'system' that they are part of and understanding that system leads to an understanding of the art. **Science and Geography:** • When designing experiments and making hypotheses scientists take into account how different components of a system (natural or human-made) can influence one another. Examples include the relationship between cells and body systems; deforestation and loss of species or landslides; and the increase in greenhouse gases and loss of ice at the north and south poles. **History:** • Historical analysis using primary and secondary sources is a systems thinking process. The exploration of how different cultures influenced one another, the factors that led to a particular historical event and topics such as migration all require an understanding of the interactions between different parts of a system.	What are the key components of this system? What are the parts of an essay? Use TEEL or PEEL to write this essay. How do they influence one another? What are the possible causes of …? How would we work out the purpose of this system? How did this influence that?

There are extraordinary learning gains that can be made if teachers invest time in creating opportunities for their students to go through the computational, design and systems thinking processes in their learning. As John Spencer and AJ Juliani (2016) point out, design and systems thinking develops learners to be empathetic, be questioners, be curious and take creative risks, be critical and creative thinkers, make connections between ideas, to think about the bigger picture and the relationship between things, be problem solvers and to work collaboratively with others towards a solution. Interestingly enough, many of these skills, behaviours and dispositions are captured by the general capabilities in the Australian Curriculum.

Perhaps the most valuable outcome that arises from focusing on the thinking frameworks is the mindset that is nurtured. Learners who have ingrained computational, design and systems thinking see the world differently. No problem is insurmountable. They bring clarity in the way they work through complexity to find a solution. They know themselves as capable learners. They are courageous and confident within themselves. These are the individuals who lead humanity forward.

Unfortunately, when schools and teachers focus on delivering the content of STEM rather than developing student thinking, the value and opportunity of the thinking frameworks within the Australian Curriculum are lost.

LAYING THE FOUNDATIONAL THINKING

One of the early steps to embedding an authentic STEM program is teachers and school leaders infusing the thinking frameworks into the way their school plans, delivers and assesses learning. To answer this challenge, it is important to step back to gain a deeper appreciation and understanding of what actually creates effective learning.

LEARNING IS BUILT ON HABITS

The brain has evolved over millions of years to be an efficient energy user. One of the major ways that the brain attempts to lower energy usage by making almost any routine into a habit. In other words, anything that we do ritually will, over time, become a subconscious habit.

As Duhigg (2014) points out in The power of habits, this energy-saving short cut has a number of huge advantages:

> *An efficient brain requires less room, which makes for a smaller head, which makes childbirth easier and therefore causes fewer infant and mother deaths. An efficient brain also allows us to stop thinking constantly about basic behaviours, such as walking and choosing what to eat. (p. 18)*

We walk every day, but for the majority of us it is a completely subconscious activity. Biomechanically, the action of walking, putting one foot in front of another in such a way that we maintain balance while we move forward, is quite a complex ballet of motion and coordination. It requires the perfect timing and coordination of many of our body systems to enable it to occur. When babies are learning to walk, the action requires a high level of conscious focus from their brains. Over time, as walking becomes routine and a habit, the action of walking requires less and less attention from the brain until it becomes subconscious.

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While our ability to make routines subconscious habits is a valuable trait for thriving in an increasingly complex world, switching to automatic does have its drawbacks in certain areas. For example, human and primate brains are susceptible to optical illusions because our optic nerves exit our retinas at a particular place. This exit area has no photoreceptors and we physically cannot 'see' when light falls on this region of our eyeballs. Yet we do not experience having a blind spot at all. What happens is that our brains mentally fill in what should be there with its best guess, based on past experience as well as the constant scanning of our eyes. The result is that our eyes and our brains can be tricked – and not just by optical illusions.

How we learn and why we have particular biases, strengths, misconceptions, responses to situations and dispositions to learning are all shaped by the brain's attempt to minimise energy usage. As we grow and interact with the world around us, our brains build a mental schema. This schema is a personal framework, woven from our experiences and emotions, which is then reinforced over time. This mental schema underpins the way we understand and interpret reality, how we communicate, what we believe, our mindset in various situations, the way we learn and our conception of ourselves. It influences what makes us happy, the way we teach, the people we connect with and those we do not, how we organise (or don't organise) ourselves, and absolutely every interaction we have.

A mental schema is not a fixed framework and it does adapt and adjust as new learning takes place. As we experience new situations, new ideas and new emotions, the brain has the capacity to form new neuronal connections and pathways as well as reclassify experiences, emotions and knowledge to arrive at a refined mental schema of the world. If particular knowledge or experiences and their associated emotions are not reinforced by usage, then the connections to those neural pathways are not reinforced and eventually end up pruned away. The more that specific neural pathways and connections are used, the stronger the connections and pathways become – and the more likely it is that the brain will use those connections and pathways automatically in a situation. This is how we learn. It also allows us to re-train and reframe our responses, actions and habits as we age and when we perceive threat.

However, if our thinking, beliefs and understandings are not examined and challenged periodically, the schema we operate from can become so automatic that we believe our perception and habits are 'just who we are' and that we cannot change. While it is not actually physically true that our brain and mental schemas cannot change, it does take significant effort to overcome our beliefs and the automaticity of our habits.

The habits and practices of individual teachers and school leaders have been shaped by experiences such as how they were taught, the way their parents interacted with and taught them, the teaching practicum they experienced, what worked when they began teaching, what new approaches they learnt in professional development sessions and even what they noticed watching other teachers in action. Equally, since schools are designed by a community of human beings, a school's culture, structures, processes and policies systemically ritualise what is considered important (and what is not) and what is valued (and what is not). This includes what time school begins and ends, the length of lessons, whether bells ring to signal a change in lessons, when staff meetings are held, what is done during meetings, how parents are communicated with, the processes and language used to deal with 'disruptive' students, the approach to professional learning and development at the school, the instructional model, the pedagogical model and so on.

What is worth every leader, teacher and stakeholder involved in each school examining and reflecting upon is this question: Does the current set of habits, beliefs, school structures and processes build the learning we wish to occur in our learning environment? This examination will enable teachers and school leaders to become more intentional in creating and ritualising new habits, strategies, school structures and processes that are aligned with the outcomes they want to achieve. In essence, when education researchers such as John Hattie (2009) identify high-effect size teaching strategies such as explicit teaching, learning intentions and success criteria, formative feedback and so on, they are identifying the specific habitual practices that make a difference to learning growth. The goal should be to consistently embed specific rituals, habitual practices and thinking frameworks throughout learning so that students internalise them and begin to think, view and interpret the world in particular ways.

DEVELOPING HIGHLY CAPABLE LEARNERS IS THE GOAL

If schools are preparing young people to be future ready in a world of rapid change, they must have a focus on developing a learning environment that nurtures young people to be problem-solvers, critical and creative thinkers, and collaborative and adaptable learners. Schools need to ensure they are embedding the rituals, practices and thinking that progressively develop students to be highly capable learners.

A key trait of highly capable learners is that they self-regulate their learning. While there are a number of frameworks describing self-regulated learning, Zimmerman and Moylan's (2009) model is one of the most influential. This cyclical model of self-regulated learning, illustrated in figure 1.5, outlines the three phases and respective processes of self-regulation (Zimmerman & Moylan, 2009):

1. The forethought phase
   Learners analyse the components of a task, set goals and plan strategies prior to commencing learning. Key processes comprise:
   - task analysis, where learners deconstruct the task and establish the strategies they will use
   - self-motivation beliefs, addressing the variables that generate and maintain the motivation to perform the task. This includes beliefs about capability, potential for success on the task and the relevance of the task to personal goals.
2. The performance phase
   Learners make use of planning from the forethought phase by implementing and remaining aware of the selected strategies while they are in use. They use self-observation and feedback to monitor their progress and motivation.
   Key processes include:
   - self-observation, where learners assess and regulate their behaviour and learning strategies for the purpose of remaining on track to achieve their goal or, if need be, alter their goal according to changed conditions
   - self-control, which is about maintaining concentration and interest using strategies such as time management, mental imagery, setting up the learning environment, self-praise and self-reward.
3. The self-reflection phase
   Learners evaluate and judge their performance against the standards established in the forethought phase against the selected goals and strategies. This phase requires learners to use observations and feedback to evaluate their results and performance and formulate causal attributions.
   Key processes are:

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- self-judgement, in which learners assess their performance against particular criteria and explain the reasons for success or failure
- self-reaction, where learners react to self-judgement and identify strategies and approaches to use in future (for example, learning strategies, effort or use of feedback).

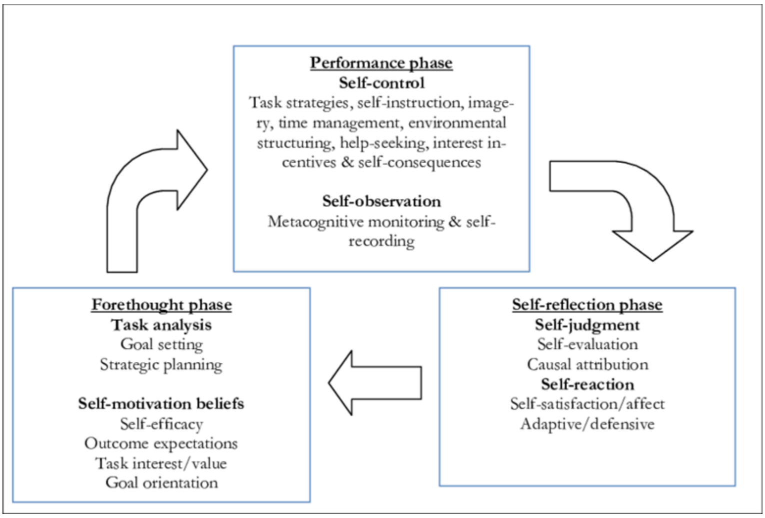

Figure 1.5: **Zimmerman and Moylan's (2009) cyclical model of self-regulation**
Source: Zimmerman and Moylan (2009)

To develop students to be highly capable learners, schools need to explicitly teach and embed the rituals, practices and thinking that progressively develop students to be self-regulated. This includes skills in:

- task analysis and goal setting
- reflecting on and addressing their feelings and self-beliefs
- self-monitoring their behaviour and the learning strategies they are using
- using feedback to self-modify their behaviour and the learning strategies they are using
- reflecting on whether they achieved their goal or not and then refining their approach for future use.

These self-regulation skills are, unsurprisingly, not only central to the systems thinking, design thinking and computational thinking frameworks but also at the heart of the general capabilities within the Australian Curriculum.

DEVELOPING THE MOTIVATION AND MINDSET TO LEARN

Self-motivation beliefs are key to self-regulation. However, it has been rare for teachers and school leaders to discuss and address how the subconscious beliefs learners and teachers influence student learning growth.

Table 1.7: ***A selection of influences and effect sizes related to student achievement***

Factor related to student achievement	Effect size	Description
Collective teacher efficacy	1.57	Teachers collaborate based upon the shared belief that their work will make a difference to student learning
Self-reported grades	1.33	Teachers find out what are the student's expectations and push the learner to exceed those expectations
Teacher estimates of student achievement	1.29	The teacher's beliefs and conceptions about a student inform their views about what students are able to achieve
Self-efficacy	0.92	A student's belief that they can perform a particular task successfully
Teacher credibility	0.90	The student's beliefs about teacher knowledge and expertise; as well as high relational trust

Source: Adapted from Hattie (2017) and Waack (2018)

Table 1.7 shows a selection of factors that influence student achievement and their effect sizes (Hattie, 2017; Waack, 2018). Evidence for Learning (2021) finds that feedback – the information given to a learner or teacher about a learner's performance relative to learning goals or outcomes – has an effect size of 0.70 and can have learning gains between three and eight months' progress depending on the area. The much larger effect sizes displayed in table 1.7 indicate that if a school explicitly supports students and teachers to reflect upon and address their beliefs then there should be significant learning progress. The implication is that there must be opportunities across the planning, teaching, learning, assessment cycle where students and teachers reflect on their beliefs and mindsets, and for strategies to be put in place to have them move beyond any that hinder learning growth.

In summary, an effective learning environment is built upon rituals, practices and thinking that:

- develop highly capable learners who think from and use the skills, practices and habits of self-regulation
- have learners and teachers self-reflect upon and address their beliefs
- create opportunities for learners to use the computational, design and system thinking frameworks across all of their learning.

CREATING A MEANINGFUL PURPOSE FOR STEM IN YOUR SCHOOL

Sustainable STEM programs are built on a shared understanding of learning and how STEM fits into a school's vision and strategic goals. Ideally this chapter has provided enough insight for a design team to come to a deep understanding of the issues, needs and challenges involved in designing an authentic STEM program. The next step is for that design team to define a clear and inspiring vision and purpose for learning and STEM within their school.

The approach that will be used is that of a design brief. A design brief normally outlines the

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aims, deliverables and scope of a design project, including any products, timing and budget. It is from the brief that everything else flows. The design brief gives direction, provides purpose and clarifies what to focus on. It also provides a way to check whether the school is on track to achieve the desired outcomes.

The following two exercises will support the development of a design brief and guide the thinking and planning involved in designing an authentic primary school STEM program.

Figure 1.6 is an example of a design brief created in the style of the 'Define 1' exercise for a Catholic school with a highly culturally diverse group of students. The design team deliberately wanted to ensure that any STEM program they developed not only addressed the curriculum requirements but also honoured and supported the community to grow and learn together

Exercise: Define 1

With the design team, use the following three prompts to produce a design brief for a STEM program at your school:

1. To design a program that ...
2. That meets the needs of ...
3. And has the benefits of ...

Design brief

To design a STEM program that:

- has students be curious and see the bigger picture, purpose and relevance of concepts being taught
- grows their capacity to be independent, self-regulated learners who can transfer their learning to new situations.

This program meets the needs of:

- gender and cultural diversity
- low cost
- engagement
- curriculum relevance (learning areas, general capabilities and cross-curriculum priorities)
- honouring the identity and past of the students and the school
- growing the confidence and competence of the students and teachers.

And has the benefits of:

- giving students agency, voice and leadership opportunities
- recapping some of the curriculum covered previously
- shifting the perception of staff, students and parents about what is possible
- creating an authentic through-line through the years that grows students as learners
- developing metacognition
- having a gradual release of responsibility where students learn to drive their own learning.

Figure 1.6: **Sample design brief**

Exercise: Define 2

Against the design brief created in 'Exercise: Define 1', answer the following questions:

- Which systems, policies, processes and roles are currently aligned?
- Which systems, policies, processes and roles are not currently aligned?
- What non-negotiable ideas and priorities could unite the school community as you design a STEM program to meet the design brief?

This second exercise allows a design team to assess where the school sits against the design brief at a given point in time. This will give an idea of potential actions to be taken to lay the groundwork for a sustainable STEM program. Some of the gaps that may be discovered in this process include:

The school does not have whole-school learning structures in place to allow for learner-driven or learner-centred learning to occur.

Teachers do not yet have the capacity to facilitate learner-driven or learner-centred learning.

- The school is constrained by the way the timetable is designed.
- The school is constrained by the available facilities.
- The school is constrained by teacher or parent beliefs and mindsets.
- The school does not yet have the curriculum documentation in place to be able to design transdisciplinary units.
- Teachers are not skilled in developing their capacity through mini action-research projects.
- Students have become passive learners over time and need to be empowered to be the drivers of their learning.
- There is a very shallow depth of understanding about self-regulation and the vision for learning in the school.

As the design team goes through these exercises, the next steps and non-negotiable priorities should become clear. In the next chapter, a systems thinking process will be used to identify how a school can begin to align itself to a design brief.

KEY POINTS

- Students come to your school with already existing habits, beliefs and learning practices they have developed over time. These influence their ability to learn – and many remain unexamined.
- Teachers and school leaders need to examine pre-existing habitual practices, structures and beliefs if they are going to design a STEM program that is sustainable, meets its purpose and nurtures future ready learners.

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- The process of examining the pre-existing beliefs and thinking will often highlight challenges that will require addressing, such as misconceptions about what STEM is, limiting teacher mindsets and the perceptions that STEM is simply yet another thing to do.
- STEM and the Australian Curriculum: Technologies can transform how learning in schools occurs if schools and teachers focus on embedding thinking frameworks with content as the vehicle for thinking and problem-solving.
- Computational, design and systems thinking are applicable in all disciplines and many teachers naturally apply the strategies, to differing extents, in their classes.
- Powerful learning is nurtured by being thoughtful about the specific rituals and habitual practices schools embed throughout their learning environment.
- To develop highly capable learners, schools need to ritualise the habits, practices and thinking that develop learners to be self-regulated. They also need to create opportunities for teachers and students to habitually self-reflect and address their beliefs about learning.
- Developing a sustainable STEM program requires the creation of a design brief that articulates the purpose of STEM in the school.