A report prepared by Learning First for the NSW Department of Education

Teaching Critical Thinking: exploring implications for Stages 4 and 5 Science and History teaching

Research Summary
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NSW GOVERNMENT

LEARNING FIRST

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Learning First conducted the analysis presented in this report. The interpretations of how these systems operate are the authors', and do not necessarily represent the views or official positions of governments or officials in the systems analysed. NSW Department of Education does not necessarily endorse the curriculum frameworks and tools discussed in this report.

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Executive Summary

Overview

Critical thinking is valued universally as an important skill for all students to develop, but there are three issues with the research base: 1) there is no simple and generally accepted definition of critical thinking, 2) there is disagreement on whether critical thinking is a generic skill or is domain-specific and 3) there is very little quality research on how to teach critical thinking. There is increasing pressure on schools to ensure students gain higher-order thinking skills, but it is hard for teachers to find reliable sources of information on exactly how to incorporate critical thinking into their teaching and learning programs.

This report has been written to assist the NSW Department of Education (the Department) to develop a practical approach to improving the teaching and learning of critical thinking skills in NSW schools. The project seeks to cut through the conceptual, and often ambiguous and noisy, debate about critical thinking and provide the Department with concrete steps it can take that have a strong rationale and potential impact. This project builds on existing work done by the Department and provides a tangible way forward.

The report focuses on science and history teaching in Stages 4 and 5. It does not review the curriculum or redefine what is taught in these domains, but rather seeks to propose solutions to assist teachers to better interpret documented curriculum and create effective teaching and learning programs. The project considers available research, case studies of other systems, and the current situation in New South Wales in order to make suggestions about what would most help teachers to improve their implementation of the syllabus and improve students' development of critical thinking in science and history in secondary school. Finally, the report highlights resources that will help to bridge the gap between documented and enacted curricula and to support the teaching of critical thinking.

The evidence in this report comes from a combination of literature review and case studies of other systems. The research literature is useful to gain insight into what is empirically known (and not yet known) about the teaching of critical thinking. The literature provides high-level insights into what teaching practices are most likely to support the development of critical thinking in students. However, the literature has limitations because so much about teaching critical thinking is still unknown. For that reason, it is also useful to look at case studies of other systems around the world to gain practical insights into different approaches that may support teaching critical thinking.

The report answers four key questions:

1. What are the critical thinking skills in science and history?
2. How do we teach critical thinking, particularly in secondary science and history?
3. How should we sequence critical thinking skills?
4. What knowledge do teachers need to teach critical thinking?

Key Findings

The key findings are summarised below for each of the three research questions.

What are the critical thinking skills in science and history?

Box 1:
Key findings: What are the critical thinking skills in science and history?

1. Critical thinking skills overlap with the disciplinary knowledge in a domain.
2. The inquiry approaches in history and science may act as useful organising frameworks for critical thinking skills.
3. Both science and history have cross-cutting concepts that may be important for critical thinking.

Finding 1: Critical thinking skills overlap with the disciplinary knowledge in a domain.

A common framework in the literature is that each domain has two major types of knowledge: substantive and disciplinary. Substantive knowledge comprises content that is established fact, whereas disciplinary knowledge comprises information about how the domain's knowledge was established. For science, disciplinary knowledge includes the process of scientific inquiry and empirical testing. In history, disciplinary knowledge includes analysis and argument based on evidence and critical historical inquiry. Science and history syllabuses share many common verbs representing learning objectives, including analyse, evaluate, interpret and argue.

Teaching experts often see critical thinking skills as being at the core of how to teach science and history disciplinary knowledge. These skills are related to ideas such as teaching students how to 'think like a historian' or 'think like a scientist'.

Finding 2: The inquiry approaches in history and science may act as useful organising frameworks for critical thinking skills.

Both science and history have a discipline inquiry process at the heart of how domain knowledge is created (see Table 1). Although called 'inquiry', discipline inquiry is different to inquiry learning. Curricula in some systems explicitly point to steps of historical or scientific inquiry that can be taught to students. In other systems, discipline inquiry is not detailed in steps but is part of a background framework that organises learning and skill development. Discipline inquiry may not always contain all critical thinking skills that are important to teach, but it is a useful conceptual framework for organising most of these skills.

Table 1: Sample inquiry skills taken from Singapore, Hong Kong, and NSW curricula

Science	History
Sample critical thinking skills in scientific inquiry	**Sample critical thinking skills in historical inquiry**
1. Questioning and predicting 2. Formulating hypotheses and predicting 3. Planning and conducting investigations with appropriate methodology 4. Analysing data and information 5. Drawing conclusions and inferring 6. Identifying limitations and reflecting	1. Asking historical questions 2. Critically analysing, interpreting, and evaluating sources 3. Constructing and substantiating historical interpretations 4. Developing arguments 5. Checking/reflecting on interpretations

There are many more skills under each inquiry stage listed in Table 1. For example, 'critically analysing sources' in history is a large umbrella skill that can be broken down into many parts for different purposes.

Finding 3: Both science and history have cross-cutting concepts that may be important for critical thinking.

Even though we speak about critical thinking as a 'skill', evidence shows that the ability to use the skill depends on knowledge. Focusing on knowledge does not mean that it is a good idea to cram as much content as possible into a lesson; instead, it is useful to consider the best ways to organise knowledge in teaching so that it takes priority and students can hold the information in their long-term memories. The ability to make connections across topics is important both for the organisation of knowledge and for the development of critical thinking skills. Science and history both have cross-cutting concepts that help students to make connections.

- In science, these concepts may include patterns, cause and effect, systems and models, flows and cycles, structure and function, and stability and change (among others).
- In history, these concepts may include continuity and change, cause and effect, and historical significance (among others).

Considering how to teach these concepts in tandem with critical thinking skills may help educators to make sense of how to fit together knowledge and skills within a teaching program.

How do we teach critical thinking, particularly in secondary science and history?

Research on teaching critical thinking is relatively limited, and even more sparse on teaching domain-specific critical thinking. We describe below what evidence does exist around the most commonly cited practices linked to critical thinking skills. Although the evidence is very limited or ambiguous for almost all these practices, teachers can still benefit from trialling them and collecting their own evidence in their classrooms about whether student critical thinking skills improve over time.

Box 2:
Key findings: How do we teach critical thinking?

1. Critical thinking skills are generally linked to domain expertise.
2. Best practices for teaching also apply to teaching critical thinking.
3. Focus on student thinking regardless of the mode of instruction.
4. In science teaching, respond to students' preconceptions and misconceptions.
5. In history teaching, help students identify recurring historical concepts.

Finding 1: Critical thinking skills are generally linked to domain expertise.

Research shows that the ability to use critical thinking skills is generally linked to domain expertise. Therefore, to support the learning and deployment of these skills it is important to create a 'knowledge rich' teaching and learning program. The content presented to students should be carefully selected and prioritised to ensure students are building knowledge at the same time as they build skills. That is not to say students cannot think critically early in their learning. Critical thinking skills do not have to wait for students to become proficient in a domain, since these skills can be built simultaneously with content knowledge, and from early on.

Finding 2: Best practices for teaching also apply to teaching critical thinking.

Many evidence-based practices for teaching in general also apply when teaching critical thinking. These include explicit teaching, structured questioning, and practice. Designing teaching to be cognizant of cognitive load theory and the development of student metacognitive skills is also important.

- *Explicit teaching*: There is ample evidence that explicit teaching results in better student learning outcomes. This is true for all instruction, but there is also evidence that explicit teaching of critical thinking skills leads to greater learning.
- *Structured questioning*: There is good evidence that structuring questions to encourage student thinking can help build critical thinking skills. Questions can be formally built into assessments, but they can also be used for in-class discussions or informal talks with students.
- *Practice*: Critical thinking skills, like all skills, require extensive practice. Some research describes the need for long-term, repeated exposure to problems/tasks that have the same deep structure but different surface structures. Other research supports using deliberate practice (practice with feedback) to support specific critical thinking skills.
- *Cognitive load theory* contains two core ideas: one, the amount of new information the human brain can process at one time is limited; and two, more information can be stored in long-term than in short-term memory. Reducing cognitive load frees the brain to focus on more challenging tasks. Teachers who understand cognitive load theory break down new skills into manageable and clearly scaffolded tasks. This approach does not mean that complex inquiry questions can't be introduced early to students, or that only older students can engage in complex thinking. Instead, the theory stipulates that instruction in the early phase should be designed to be more teacher-led, and students should be supported in learning new concepts. Student-led learning should be introduced later in the teaching and learning program.
- *Metacognition* means "thinking about thinking".[1] Some researchers view metacognition as a form of critical thinking because it involves knowing strategies to solve a problem and how to make decisions about deploying those strategies. Metacognition might also be viewed as a supporting condition for critical thinking because monitoring the quality of one's thoughts helps ensure high-quality thinking.

Finding 3: Focus on student thinking regardless of the mode of instruction.

There is evidence that the mode of instruction – teaching from a textbook versus teaching with 'hands on' methods, for example – matters less for developing critical thinking skills in science compared to the ability of teachers to probe student thinking. Methods such as active learning and inquiry learning have been found to have mixed results, and this is likely due to the varied ways the methods are implemented in the classroom.

In science teaching, some examples of common methods include active learning and inquiry learning:

- *Active learning* methods in science may include guided inquiry learning, case-based teaching, problem-based learning, and flipped classrooms (among others). There is some evidence that active learning is more effective than passive learning in certain contexts – especially when students collaborate in learning. Most literature on active learning emphasises that because both teachers and students find it difficult to switch to new teaching and learning practices, teachers are likely to need a lot of support in understanding how to make active learning effective.
- *Inquiry learning*: Many studies show that inquiry teaching practices for supporting student engagement as well as learning in

1 NSW Department of Education, '[Metacognition](#)', Education for a Changing World website 2021, accessed 23 June 2022.

science have positive effects. Other studies show that too much inquiry teaching (especially when student-led) will hinder learning. Therefore, teachers may need guidance to deploy inquiry practices effectively to support student achievement. But when done well, inquiry can help with the teaching of critical thinking skills in science.

In history teaching, methods reviewed in the literature include depth studies, historical inquiry questions, and Reading Like a Historian (a Stanford University initiative).

- *Depth studies*: Depth studies, which include student-led investigations, can be used to develop a deeper knowledge of one or more concepts found within a syllabus. There is very little evidence on depth studies and their effectiveness, but they are used today in various forms to teach history across the world, including in the NSW Curriculum. There is a substantial amount of evidence that teaching for depth versus breadth is more effective for student learning, especially for higher-order thinking skill development. However, this research is not available specifically for history teaching. If it is assumed that similar principles apply to history, organising instruction around depth studies might be a good idea. Yet the effectiveness of depth studies is likely to depend a great deal on the specifics of how students are taught – for example, what probing questions teachers ask and what scaffolds they provide to support student learning.
- *The inquiry question*: A key component of historical inquiry is the inquiry question. The inquiry question acts as a device to help teachers plan a lesson or a unit. It is meant to engage students by capturing their interest as well as connecting their learning from one topic to the next. Despite the similarity of terms, the historical inquiry question is not associated with the process of student-led inquiry since it is meant to be more teacher-directed. A well-crafted inquiry question seeks to engage students in deeper thought about the lesson rather than just seeking easy answers.
- *Reading Like a Historian*: There are very few studies of specific methods for teaching critical thinking in history, but one recent method contains a small amount of promising evidence. Reading Like a Historian is a 'document-based lesson' that uses source-reading strategies to better enable students to engage in historical inquiry. These practices combine the teaching of content knowledge and disciplinary inquiry. Students are asked to interrogate, and then reconcile, the historical accounts in multiple texts in order to arrive at their own interpretations.

Finding 4: In science teaching, respond to students' preconceptions and misconceptions.

Teachers can support critical thinking in science by challenging students' thinking. Among other strategies, they can explicitly tackle student preconceptions and misconceptions about different topics in science.

Finding 5: In history teaching, help students explore history by applying recurring concepts.

History curricula across many systems share similar second-order concepts that are essential to the practice of history. These include cause, change, historical significance and others. Literature on history teaching emphasises that teachers can help students to notice that these concepts re-occur throughout lessons involving different content. The teaching strategy of connecting ideas across diverse content is aligned to the research on how to teach critical thinking.

How should we sequence critical thinking skills?

As with most critical thinking research, concrete information about the ideal sequence for teaching various critical thinking skills is limited. Nevertheless, the following general frameworks can be a useful starting point for thinking about how skills progress.

We suggest using three types of frameworks for designing critical thinking skill sequences: 1) Domain-specific skills progressions (the contents of the NSW Curriculum, for example); 2) General critical thinking skills frameworks (Bloom's Taxonomy or the ACARA learning continuum, for example); and 3) Pedagogical principles for sequencing (evidence-based approaches such as those in Rosenshine, 2012, for example). Figure 1 shows the three types of frameworks that can be used to develop a critical thinking skills sequence. Each framework is described further in Section 4.

Figure 1: Framework for designing a critical thinking skills teaching sequence

Domain specific skills progression

History examples:

- Analysis and use of sources
- Historical investigation and research

Science examples:

- Questioning and Predicting
- Processing and Analysing Data and Information
- Problem Solving

General critical thinking skills frameworks

- ACARA Critical and Creative Thinking learning continuum
- Bloom's Taxonomy
- Solo Taxonomy

Pedagogical principles for sequencing

- Break down skills into smaller steps
- Provide scaffolds for difficult tasks
- Require lots of practice
- Review previous learning regularly

Elements of each framework can be combined to create a critical thinking skills sequence

What knowledge do teachers need to teach critical thinking?

There is a growing consensus that two types of subject expertise are necessary to teach well:

- *Content knowledge*: a deep foundation of factual knowledge about the subject being taught
- *Pedagogical content knowledge*: understanding how to best teach the subject

New ideas are emerging about the specific types of knowledge that teachers may need to teach *critical thinking*. These theories build on the idea of pedagogical content knowledge and specify that teachers are likely to need a specific body of knowledge which includes how to teach critical thinking in particular domains.

For example, there are four potential categories of knowledge for teaching critical thinking:

1. *Critical thinking knowledge*: General knowledge about critical thinking and what it looks like.
2. *Critical thinking content knowledge*: The unique features of critical thinking within a specific domain (such as science).
3. *Critical thinking pedagogical knowledge*: Knowledge of how to teach critical thinking.
4. *Critical thinking pedagogical content knowledge*: Knowledge of how to teach critical thinking in a specific domain (such as in a science class).

1 Introduction

This report was written to assist the Department to develop practical approaches to improve the teaching and learning of critical thinking skills in NSW schools. It focuses on science and history teaching in Stages 4 and 5. It does not review the curriculum or redefine what is taught in these domains, but rather seeks to propose solutions to better support teachers in interpreting documented curriculum and creating effective teaching and learning programs. The project looks at available research, case studies of other systems, and the current situation in New South Wales in order to suggest changes that would most help teachers to improve their implementation of the syllabus and improve students' development of critical thinking in science and history in high school.

The report focuses on the research on the teaching of critical thinking skills in science and history and case studies of other systems. It also highlights resources that will help to bridge the gap between documented and enacted curricula and support the teaching of critical thinking.

1.1 Report structure

The report summarises evidence on three key research questions:

1. What are the critical thinking skills in science and history?
2. What does the evidence say about the teaching of critical thinking, particularly in secondary science and history?
3. What are some example guidelines for useful critical thinking resources for teachers?

1.2 Methodology

The evidence in this report comes from a combination of a literature review and case studies of other systems. Research literature is useful to gain insight into what is empirically known (and not yet known) about the teaching of critical thinking. The literature provides high-level insights into what teaching practices are most likely to support the development of critical thinking in students. Yet the literature has limitations because so much about critical thinking teaching is still unknown. For that reason, it is also useful to look at case studies of other systems around the world in order to gain practical insights into different approaches that may support critical thinking teaching.

1.2.1 Literature review

The literature review looked at three key questions:

1. What are the critical thinking skills in science and history?
2. What does the evidence say about the teaching of critical thinking, particularly in secondary science and history?
3. What are some example guidelines for useful critical thinking resources for teachers?

Each of these questions has a very small empirical research base, but there are some relevant findings in the last few decades about teaching critical thinking in general, and specifically for science and history. Much of the evidence on each of the three research questions is based on theory or logic rather than high-quality empirical research. For example, because there are very few randomised controlled trials of different methods to teach critical thinking, there is not much concrete causal evidence available. Figure 2 shows a sample hierarchy of evidence for education research.

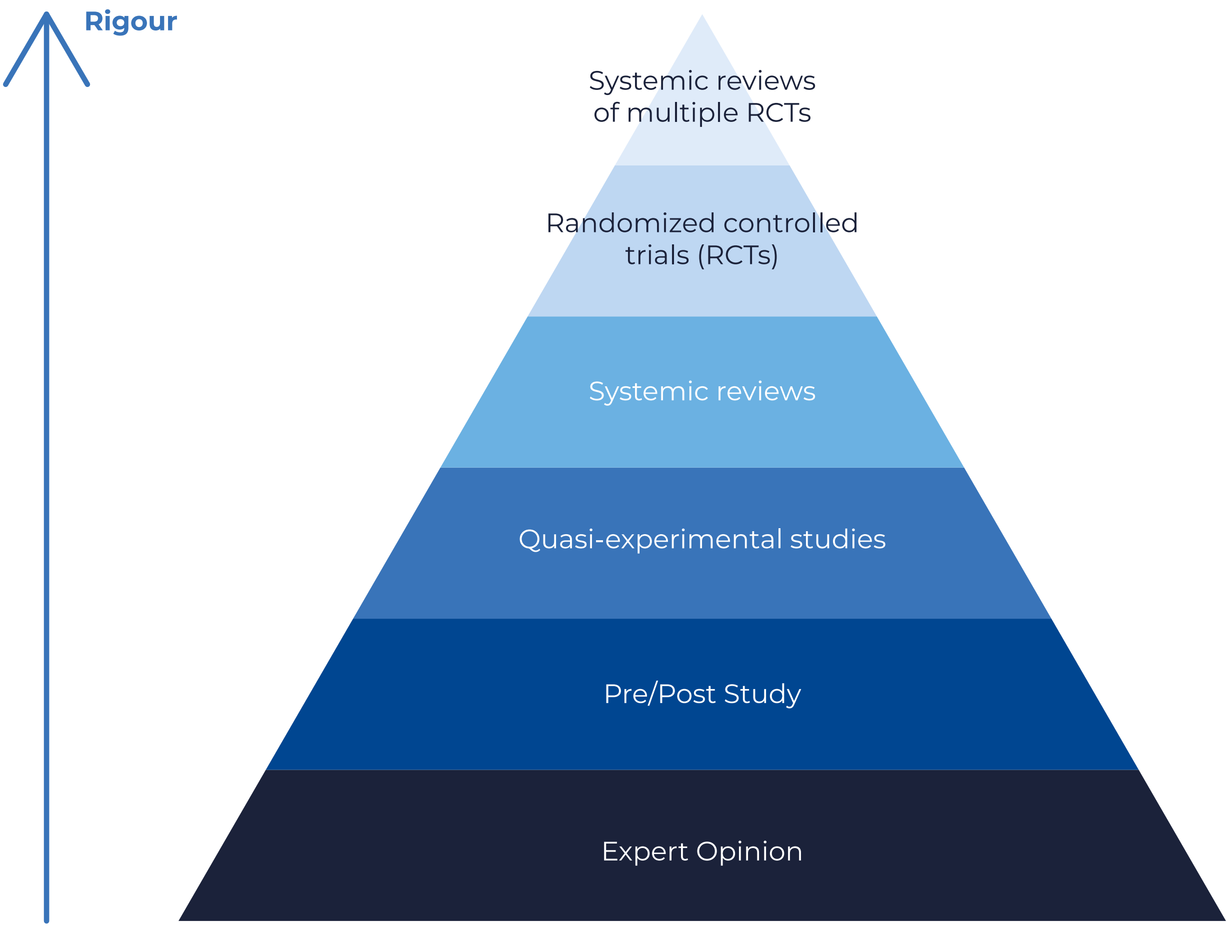
Since almost all the critical thinking research available is from the lower tiers, it is less rigorous and less able to be used as conclusive evidence that a particular teaching method will 'work' for improving critical thinking skills in students.

While the limited amount of rigorous research means that some evidence is not robust, the research nevertheless has value. In the absence of anything more rigorous, a lot can be learned from lower-tier evidence, especially when most experts generally agree.

Where possible, this report highlights when evidence is more conclusive, along with areas of more disagreement among experts. With more conclusive evidence, the NSW system can be more confident of the most effective teaching practices to recommend to teachers. But since this type of evidence is rare, most ideas for the teaching of critical thinking will need to be trialled and monitored over time to ensure they are improving student outcomes.

Figure 2: Sample hierarchy of evidence

Source: A Leigh, 'What evidence should policymakers use?', *Economic Roundup*, 2009, 127-43.



1.2.2 Case studies

This report uses case studies from Hong Kong and Singapore to show what different systems around the world are doing to improve the teaching of critical thinking in schools. Hong Kong and Singapore were selected because they are high-performing systems with detailed curriculum implementation information freely available in English. They also have some characteristics which may make them similar to NSW. First, both cater for diverse student backgrounds. Singapore and Hong Kong both have high levels of immigration, and both systems are bi- or trilingual – teaching students their native languages as well as English. Hong Kong is very socioeconomically diverse with high levels of student poverty but is seen as a model around the world for educational equity. A major difference, of course, is that these systems are large metropolitan areas whereas NSW is geographically diverse with many more rural and isolated schools. Nevertheless, any system can learn from Singapore and Hong Kong's well-established (and very different) approaches to providing teachers with support and resources on teaching critical thinking and other skills.

Even though Singapore and Hong Kong may seem similar from the outside, they have very different approaches to education. Singapore is known for having the highest achievers in the world, but the country has been criticised for being inequitable because it streams students into academic and technical track schools at an early age. Singapore has a strong emphasis on meritocracy and high performance in schools and across all sectors. Its approach to equity is to ensure that no students leave school with gaps in foundational knowledge, but the system is less concerned with minimising the variance in student outcomes. Singapore is extremely future-oriented and is constantly improving and changing its teaching with 21st century goals in mind. The country strongly emphasises teacher education, with only one initial teacher education provider for the whole system.

Hong Kong, on the other hand, is known as one of the world's most equitable education systems. The richest and poorest students in Hong Kong differ less in achievement than in most other systems. While maintaining a strong focus on equity, Hong Kong still achieves high performance overall. Curriculum documentation emphasises a focus on equity and on ensuring every student has access to the same education, the same standards, and the same support to achieve basic proficiency in all domains. Hong Kong has also focused on 21st century skills since 2000.

In this report, we also provide examples from other systems, including the UK, the US, and the OECD at large, in order to highlight even more approaches to teaching critical thinking.

1.2.3 Current situation in NSW

The recommendations in this report are based partially on evidence collected about what critical thinking teaching looks like at present in NSW. Each piece of data collected has limitations but analysed together, they form the best picture available of the current situation. There is clear evidence that the teaching of critical thinking is happening in many different ways across the system. This report uses evidence from the following sources:

Evidence of student learning

NAP-SL, PISA, and TIMSS are three large-scale assessments that provide data on secondary science learning. These are general assessments and not specific to critical thinking learning. However, each assessment is designed to assess different levels of student learning, with the more advanced levels closely linked to critical thinking in science. Unfortunately, there is no assessment data available for the history domain.

Evidence from teacher interviews

A critical element of this project was engagement with NSW teachers to understand the current issues affecting the teaching of critical thinking, as well as opportunities to improve teaching approaches across the system. A small sample of history and science teachers in Stages 4 and 5 were invited to participate in semi-structured interviews at two points: August and November 2020. The goal was to gather diverse perspectives, including from small and large schools, schools serving low- and high-SES communities, and teachers with a range of experience, from novice to highly experienced, including subject head teachers.

The interviews had two main goals: (1) to document the current realities teachers face in understanding, planning for, and executing instruction aimed at enhancing student critical thinking and (2) to hear teacher ideas about what would help improve the teaching of critical thinking.

Learning First requested two interviews from participants, one in August and a follow-up in November, each lasting about 60 minutes. Twelve teachers were interviewed. Due to the impact of COVID-19 disruptions on schools, fewer teachers were interviewed than originally planned. Acknowledging that the captured sample was not sufficiently representative of NSW teachers, insights from these interviews have been incorporated into this report where appropriate, but are not separately reported in this publication.

NSW Syllabuses

In line with the Australian Curriculum, in NSW schools critical thinking is defined as a general capability (within the Critical and Creative Thinking capability) and taught across all subjects. The NSW syllabuses provide teachers with information about what domain-specific critical thinking skills are important. Some parts of the syllabus are explicit about providing this information: for example, using an icon to point to content that has been identified as including critical and creating thinking. But syllabus components such as the Stage Statements and Aims also provide important context to teachers about critical thinking skills. This report analyses the current science and history syllabuses in NSW for what they say – both explicitly and implicitly – about teaching critical thinking.

2 What are the critical thinking skills in science and history?

Critical thinking is valued universally as an important skill for all students to develop, but there are three problems with the research base: 1) there is no simple and generally accepted definition of critical thinking, 2) there is disagreement on whether critical thinking is a generic or domain-specific skill; and 3) there is very little quality research (especially domain-specific research) on how to teach critical thinking.

With any desired outcome of education, it is helpful to think about the end goal, and then backwards plan how to get there. It is important, therefore, to consider creating critical thinkers, but the hard work is in understanding what has to be done within schools, between teachers and students, to achieve that goal. This report, therefore, focuses on critical thinking research that is most closely related to teaching practices, particularly for high school students.

> It often remains unclear for teachers what creativity and critical thinking (and some other complex thinking skills) actually mean and entail in their daily teaching practice. Rather than a problem of 'resistance to change' or 'innovation fatigue', the lack of implementation comes from a lack of clarity about what big concepts actually mean, and how they translate into teaching, learning and formative assessment.[2]

2.1 Differing definitions of critical thinking

There are many different ways to define critical thinking, but most definitions consider critical thinking as being able to judge, analyse, and solve problems. Critical thinking is also marked by a disposition of open-mindedness and the ability to change beliefs based on evidence.[3] The literature often sees notions of 'critical thinking' and 'higher-order thinking' as equivalent.[4]

The Australian Curriculum identifies critical thinking as being "at the core of most intellectual activity that involves students learning to recognise or develop an argument, use evidence in support of that argument, draw reasoned conclusions, and use information to solve problems."[5] The Australian Curriculum closely links critical thinking to creative thinking. However, while many researchers include aspects of creativity in their definition of critical thinking, the two are not always tied together.

The lack of a single, clear definition of critical thinking skills is a common problem in research about how to teach these skills.

2 OECD, Fostering Students' Creativity and Critical Thinking: rubrics and lesson plans, OECD website 2019, accessed 23 April 2020.

3 A Charoula & V Nicos, 'Instructional effects on critical thinking: Performance on ill-defined issues', *Learning and Instruction*, 2009, 19: 322-344.

4 T Anderson, C Howe, R Soden, J Halliday & J Low, 'Peer interaction and the learning of critical thinking skills in further education students', *Instructional Science*, 2001, 29(1):1-32; R Paul, *Critical thinking: How to prepare students for a rapidly changing world* 1991, 1993, Foundation for Critical Thinking, Santa Rosa, CA, 1995.

5 ACARA, Critical and Creative Thinking, Australian Curriculum, 2018.

Table 2: Sample definitions of critical thinking

Sample definitions of critical thinking
"Thinking that facilitates good judgment because it relies upon criteria; is self-correcting; and is sensitive to context."[6]
"Purposeful thinking in which the thinker systematically and habitually imposes criteria and intellectual standards upon the thinking."[7]
"…seeing both sides of an issue, being open to new evidence that disconfirms your ideas, reasoning dispassionately, demanding that claims be backed by evidence, deducing and inferring conclusions from available facts, solving problems, and so forth."[8]
"An active process involving a number of denotable mental operations such as induction, deduction, reasoning, sequencing, classification and definition of relationships."[9]
"…(i) as judgement; (ii) as skepticism; (iii) as a simple originality; (iv) as sensitive readings; (v) as rationality; (vi) as an activist engagement with knowledge; and (vii) as self-reflexivity."[10]
"…at the core of most intellectual activity that involves students learning to recognise or develop an argument, use evidence in support of that argument, draw reasoned conclusions, and use information to solve problems."[11]
"Questioning and evaluating ideas and solutions."[12]

Singapore's 21st Century Competencies Framework incorporates *Critical and Inventive Thinking*. This framework cuts across curriculum areas and is included within each subject syllabus.[13] Each syllabus refers to this framework but also has its own discipline-specific framework that contains elements of critical thinking even if these frameworks do not use the exact same language as the 21st Century Competencies Framework.

Hong Kong incorporates critical thinking, creativity and problem solving in the generic skills the Education Development Bureau expects students to develop throughout their schooling.[14] However, critical thinking is not defined generically, only within each syllabus.

6 M Lipman, *Thinking in Education*, Cambridge University Press, Cambridge, 2003.
7 R Paul, *Critical thinking: How to prepare students for a rapidly changing world*, Foundation for Critical Thinking, Santa Rosa, 1995.
8 D Willingham, 'Critical Thinking: Why is it so hard to teach?', *American Educator*, 2007, 31: 8-19.
9 I Sigel, 'A Constructivist Perspective for Teaching Thinking', *Educational Leadership*, 1984.
10 TJ Moore, 'Critical Thinking and Disciplinary Thinking: A Continuing Debate', *Higher Education Research and Development*, 2011, 30(3):261-274.
11 ACARA, Critical and Creative Thinking
12 OECD, 'The Future of Education and Skills: Education 2030', *6th Informal Working Group (IWG) meeting*, 23-25 October 2017, Paris.
13 Singapore Ministry of Education, '21st Century Competencies', Singapore Ministry of Education website, 2021, accessed 25 May 2022.
14 Education Bureau of the Government of Hong Kong Special Administrative Region, 'The School Curriculum Framework', Education Bureau website, 2021, accessed 25 May 2022.

2.2 Domain specific or general skill?

A key question for the teaching of critical thinking skills is whether they can be taught generally or whether they are subject-specific. At the heart of this question is how *transferable* researchers think critical thinking skills are. That is, if a student learns a critical thinking skill in one context, will s/he be able to transfer that skill to another context? An example would be: If a student learns a problem-solving skill in maths, will s/he be able to apply the same problem-solving skill to a science project?

This report focuses on looking at this question for the practicalities of teaching. The preponderance of evidence in the literature appears to show that critical thinking ability does improve through discipline teaching, but most general critical thinking teaching programs show little to no effect. For example, a 2016 meta-analysis concluded: "It is unlikely that additional investment in domain-general critical thinking will provide a solution to our problems."[15] This is similar to findings from other meta-analyses, for example Niu, Behar-Horenstein, & Garvan's 2013 analysis which said, "the finding that students' discipline predicts the treatment effect of instructional interventions is also in line with the conclusion of previous research that the development of critical thinking is subject specific."[16]

Most empirical evidence suggests that critical thinking skills are better taught in domain-specific settings. Even much non-empirical literature suggests that because definitions of critical thinking vary so widely, it is better to conceptualise the teaching of critical thinking as specific to domains, each of which may have its own vision of what the end goal of critical thinking teaching looks like.[17]

2.3 Common teaching frameworks that involve critical thinking

The idea that students need critical thinking skills is not new. Although often portrayed as uniquely important for the 21st century, critical thinking skills, while often described with different terminology, have been part of teaching and curriculum for decades. This history is useful because there are already widely used teaching frameworks that incorporate a version of critical thinking skills, and most teachers are familiar with critical thinking and/or the concept of higher-order thinking skills.

One commonly used framework is Bloom's Taxonomy. In 1956, Benjamin Bloom (and collaborators) published a framework for categorising educational goals called Taxonomy of Educational Objectives, also known as "Bloom's Taxonomy". The authors sought to classify different thinking behaviours that they believed were important to learning. Generations of teachers and college instructors have applied this framework in their teaching.[18] The original Bloom's Taxonomy consisted of six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. The categories after Knowledge were presented as "skills and abilities," with the understanding that knowledge was the necessary precondition for putting these skills and abilities into practice.

15 CR Huber & NR Kuncel, ' Does College Teach Critical Thinking? A Meta-Analysis', *Review of Educational Research*, 2016.

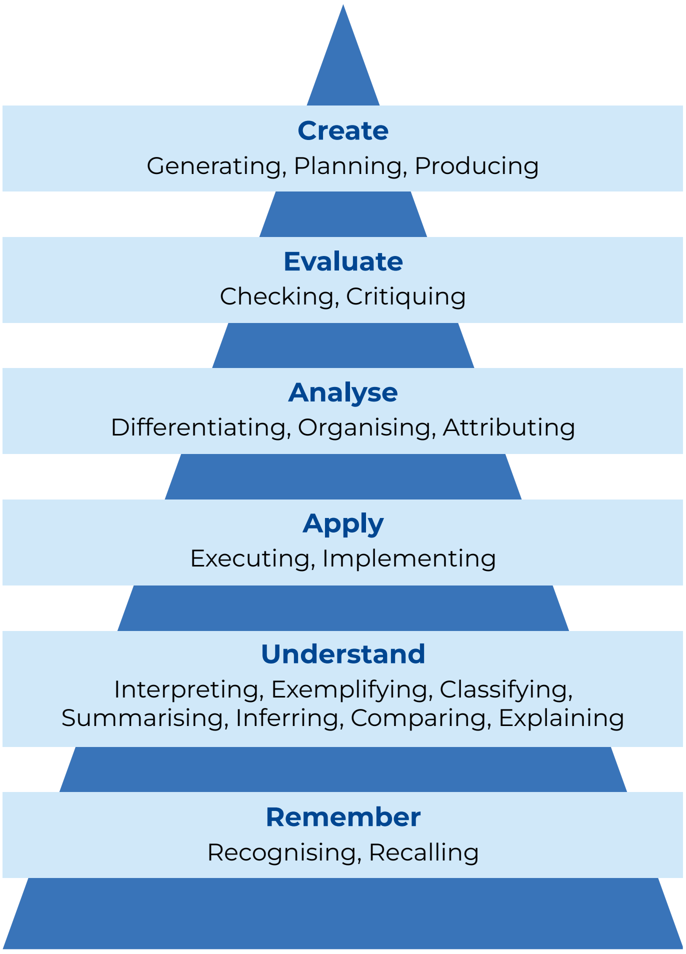
16 L Niu, LS Behar-Horenstein & CW Garvan, 'Do Instructional Interventions Influence College Students' Critical Thinking Skills? A Meta-Analysis', *Educational Research Review* 2013, 9:114-128.

17 TJ Moore, 'Critical Thinking and Disciplinary Thinking: A Continuing Debate', *Higher Education Research and Development*, 2011, 30(3):261-274.

18 P Armstrong, 'Blooms Taxonomy', Vanderbilt University Center for Teaching, 2010.

Figure 3: 2001 Revised Bloom's Taxonomy

Six Cognitive Processes



In 2001, a revision of Bloom's Taxonomy called *A Taxonomy for Teaching, Learning, and Assessment* was published. The authors of the revised taxonomy used verbs and gerunds to label their categories rather than the nouns of the original taxonomy. These "action words" describe the cognitive processes by which thinkers encounter and work with knowledge.[19]

The authors say that having an organised set of objectives helps teachers to:

- plan and deliver appropriate instruction;
- design valid assessment tasks and strategies; and
- ensure that instruction and assessment are aligned with the objectives.

Types of Knowledge Used in Cognition

1. Factual Knowledge

- Knowledge of terminology
- Knowledge of specific details and elements

2. Conceptual Knowledge

- Knowledge of classifications and categories
- Knowledge of principles and generalizations
- Knowledge of theories, models, and structures

3. Procedural Knowledge

- Knowledge of subject-specific skills and algorithms
- Knowledge of subject-specific techniques and methods
- Knowledge of criteria for determining when to use appropriate procedures

4. Metacognitive Knowledge

- Strategic Knowledge
- Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
- Self-knowledge

19 Armstrong, 'Blooms Taxonomy'.

The fallacy of focusing only on higher order skills

Since publication of Bloom's Taxonomy, educators around the world have classified different types of skills they aspire to teach students. Some have resorted to classifying skills on the bottom of the pyramid as 'low-level thinking' and the upper pyramid as 'higher order thinking'. The result has been that teachers have been told to reduce their emphasis on low-level thinking and instead focus mostly on higher order skills. This is not in line with the research behind Bloom's Taxonomy, which emphasises that the base of the pyramid is the *foundation* for the higher-level thought. In other words, you cannot think critically without first accessing a factual knowledge base.

Here is an example of how historians approach analysis of a historical document:

> To the historians, questions began at the base of the pyramid: "What am I looking at?" one asked. "A diary? A secret communiqué? A government pronouncement?" They wanted to know when it was written and what else was going on at the time. For them, critical thinking meant determining the knowledge they needed to better understand the document and its time… The high school students, on the other hand, typically encountered this document and issued judgments. In doing so, they closed the book on learning.[20]

20 S Wineburg & J Schneider, 'Inverting Bloom's Taxonomy', Education Week website, 2 October 2009, accessed 24 June 2022.

A similar framework used by some teachers in NSW is the SOLO model (Structure of the Observed Learning Outcomes).[21] SOLO is used in the NSW VALID Science assessments, so science teachers may be familiar with it and may have been trained to use SOLO for assessment.

SOLO differs from Bloom's Taxonomy in that it is more about interpreting natural growth stages in learning material of any complexity.[22] SOLO has five 'modes' and learning can occur in one or multiple modes. Within each mode are three response levels: (1) A unistructural response that includes only one relevant piece of information, (2) a multi-structural response that includes several relevant independent pieces of information, and (3) a relational response that integrates several relevant pieces of information. These three response levels go through at least two cycles – representing the cyclical nature of learning. For example, on the NSW VALID Science assessments, student responses can be categorised as "Cycle 1: multi-structural" which means students have two or more ideas below their stage or "Cycle 2: multi-structural" which means students have two or more ideas at their stage level.

Researchers believe that 'lower-order' thinking occurs at the unistructural and multi-structural levels, while 'higher-order' thinking is relational.

21 J Pegg, 'Promoting the acquisition of higher order skills and understandings in primary and secondary mathematics', *Teaching Mathematics*, 2010, 4.

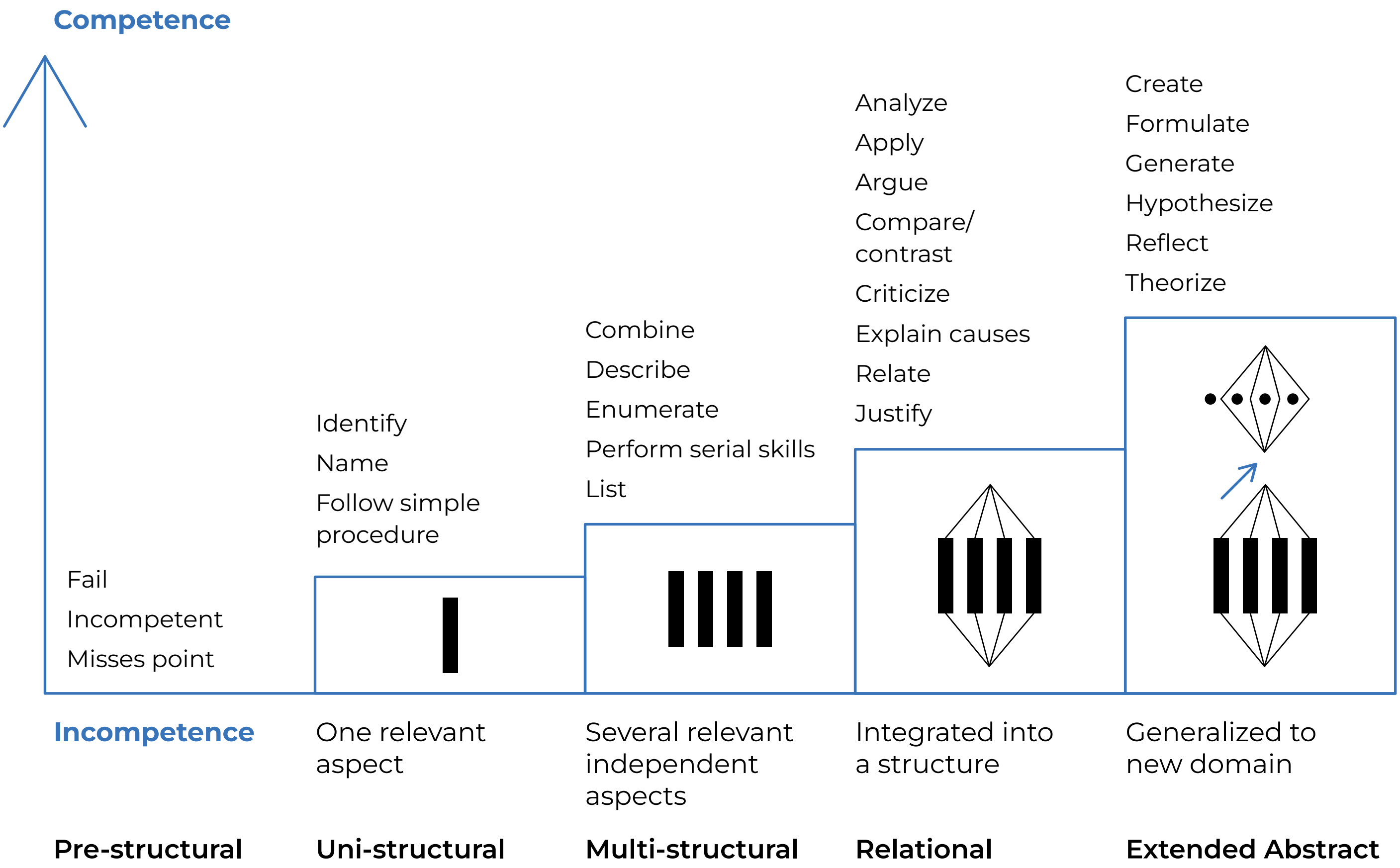
22 J Biggs & K Collis, *Evaluating the quality of learning: The SOLO taxonomy*, Academic Press, New York, 1982.

Table 3: SOLO Taxonomy and connection to critical thinking

Response level	Type of thinking	Description
Unistructural and Multi-structural	Lower order	Recall single or multiple ideas, know basic facts, undertake routine tasks by applying standard algorithms
Relational	Higher order	Integrate information and make personal connections; demonstrate some flexibility in their work; undertake problems without relying on step-by-step learnt algorithms; see novel connections not previously taught; have an overview of the concept under consideration and how different aspects of the concept are linked; show insight – able to undertake 'new' questions; and provide reasonable evidence of understanding

Figure 4: SOLO Taxonomy diagram with sample verbs indicating levels of understanding

Source: J Biggs, SOLO Taxonomy, John Biggs website, n.d., accessed 25 May 2022.



Researchers using the SOLO model believe it can help teachers to design assessments – helping them choose items that are appropriate to the level of learning desired, and also to judge student responses at different levels of learning and understanding.

However, as with Bloom's Taxonomy, some researchers are worried that SOLO could be misinterpreted to encourage teachers to focus only on higher-order thinking skills, while the framework actually encourages higher-order skills to be built on a strong foundation of lower-order skills.[23]

> An implication of the SOLO hierarchy is that higher-order skills and understandings…are built upon the acquisition of lower-order skills and understandings. Working from a developmental cognitive perspective, such as the SOLO model, exposes as fanciful and counterproductive 'common-sense' expectations of teachers: 'that almost all the time their students should be engaged in higher-order thinking'.[24]

2.4 Possible differences between critical thinking in science and history

Science and history syllabuses share many common verbs representing learning objectives, including analyse, evaluate, interpret, argue. In many systems, both domains also have a focus on inquiry – scientific or historical. But there are some differences between the domains, which might influence how critical thinking is taught. One example is the way knowledge is constructed in each domain. In science, there is a well-known scientific process, and in many classrooms, students practice the steps of this process as part of experiments. The outcome of these experiments is often fairly definitive – students have a hypothesis that they test using observational data. This approach mimics how most adults view science: as having relatively clear and evidence-based answers. Although many scientific studies are in reality not so conclusive, the discipline is generally striving to get a very high level of confidence (for example, 95 per cent confidence) in many of its findings.

History teaching in schools, by contrast, is sometimes misunderstood as being solely focused on facts and stories about the past and less on teaching a process of historical inquiry.[25] But professional historians follow a process that resembles that of scientists in analysing historical evidence and drawing conclusions. Since both science and history emphasise inquiry, they share many similarities in the types of skills students learn. For example, both scientific and historical inquiry models often have at least three key steps: pose questions, analyse evidence, and make an evaluation. What may be different is that science inquiry tends to be more linear, and thus the treatment of previous research builds on the evidence base, whereas in history the goal is more to develop one's own arguments.[26] As shown in Figure 6: General differences between secondary history and science, science knowledge is not normally 'up for grabs' by students in quite the way knowledge is in philosophy, literature or history.[27]

Each domain commonly has two major types of knowledge: substantive and disciplinary knowledge (see Figure 5).[28] Substantive knowledge is the content that is established fact, whereas disciplinary knowledge is information about how the domain's knowledge was established. In science, disciplinary knowledge includes the process of scientific inquiry and empirical testing. In history, it includes analysis and argument based on evidence and critical historical inquiry.[29]

23 Pegg, 'Promoting the acquisition of higher-order skills'.

24 Pegg, 'Promoting the acquisition of higher order skills'.

25 For example in LK Alkana, 'Teaching Critical Thinking with Historical Methodology', *Perspectives on History*, 1992: "It is true, historians are critical thinkers, but the discipline of history is often misunderstood as being too concerned with content over process (in much the same way as critical thinking is sometimes misrepresented as stressing process over knowledge)."

26 Discussions about the difference between historical and science inquiry almost exclusively reside in literature written by historians, because historians usually are comparing their methods to the scientific method. For example, S Ekecrantz, 'Academic Critical Thinking, Research Literacy And Undergraduate History', *International Journal of Historical Learning, Teaching and Research*. 2017, 15(1) writes: "In more linear text traditions, like Economics, the compilation of previous research can be seen as more integrated with the empirical results. To cite someone else's work in such disciplines generally implies that the author presents this as the best and most relevant piece of work, agrees with its results and builds on them…This includes iterative systematic reviews, quantitative meta-analyses and syntheses, compiled according to strict and shared criteria. Historians researching religious heterodoxy in early reformation Antwerp relate to a quite different type of body of research and need to do this in other ways. Some social sciences can be placed somewhere in between such extremes. Historians – and their students – obviously engage critically with previous research, but in comparison with some other disciplines, this may more often relate directly to the interpretations of sources."

27 C Counsell, Taking Curriculum Seriously, Impact, 12 September 2018.

28 P Lee & R Ashby, Progression in Historical Understanding among students ages 7-14, in PN Stearns, P Seixas & S Wineburg (eds) *Knowing, Teaching and Learning History: National and International Perspectives*, New York University Press, New York, 2000.

29 Counsell, Taking Curriculum Seriously.

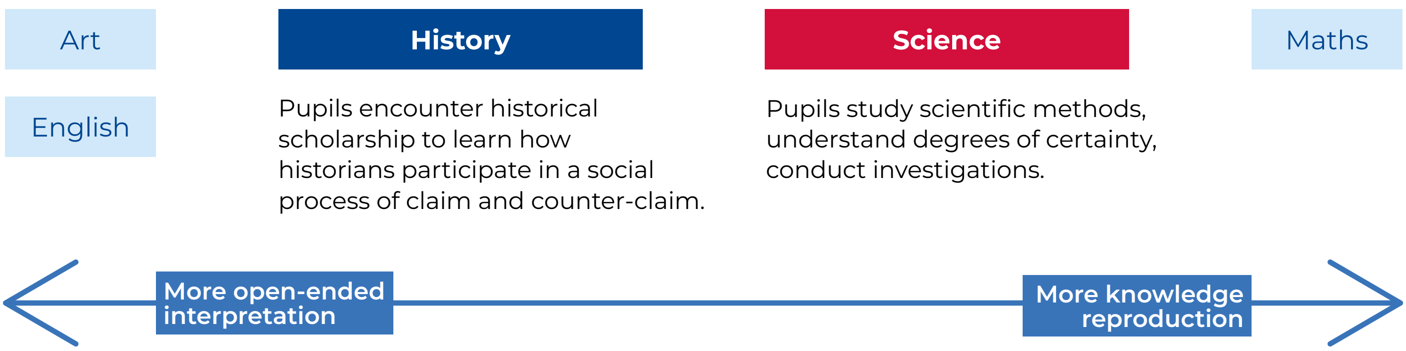
Figure 5: Two types of knowledge in a domain

Substantive Knowledge	Disciplinary Knowledge
The content that teachers teach **as established fact**.	What pupils learn about **how domain knowledge was established**. It's degree of certainty and how it continues to be revised by scholars, artists or professional practice.
Example: Knowing percentages, the Treaty of Versailles, or prokaryotic celss. The material presented as given.	**Example:** Empirical testing in science, argumentation in philosophy/history, logic in mathematics or beauty in the arts.

Source: P Lee & R Ashby, Progression in Historical Understanding among students ages 7-14, in PN Stearns, P Seixas & S Wineburg (eds) Knowing, Teaching and Learning History: National and International Perspectives, New York University Press, New York, 2000; C Counsell, [*Taking Curriculum Seriously*], Impact, 12 September 2018.

Note: Disciplinary knowledge is sometimes called procedural knowledge, but other researchers make a firm distinction between the two.

Figure 6: General differences between secondary history and science



In science, conclusions are not normally 'up for grabs' by pupils in quite the way they are in philosophy, literature or history, where argumentation itself is the method.

Source: *Counsell, Taking Curriculum Seriously.*

Note: This is an example of general differences between domains, but this framework will of course not apply to each and every learning objective. Reality is always more nuanced than what can be fit into a single framework.

2.5 Critical thinking in secondary science

Critical thinking in most definitions is similar to expert scientific thinking. Scientific thinking is the ability to generate, test, and evaluate claims, data, and theories,[30] which tends to be how critical thinking is taught and framed in science. Indeed, jurisdictions make these links explicit in curriculum documentation. For example, ACARA specifies that critical thinking is important for the scientific inquiry process, while Singapore's Science Curriculum Framework references critical thinking skills as necessary for an inquiry.

Critical thinking skills are involved in each step of the scientific method (or inquiry process). Students must generate hypotheses and make predictions based on scientific theories and knowledge. They must design a methodology that tests these hypotheses and interpret and evaluate the data gathered in experiments. They must then analyse their results, draw conclusions and reflect on the process and identify limitations to the experimental design.

2.5.1 Types of critical thinking skills

The core of most research on critical thinking in science is the scientific inquiry process. This process is not always called 'inquiry' – sometimes it is called empirical testing, the scientific method, or research skills. But underneath the different terms lie similar skills. Recent literature on secondary science teaching is more focused on metacognitive skills, but skills like weighing evidence to draw conclusions, or analysing the reliability of knowledge are commonly mentioned in current literature as well as in decades-old research.

Recently, there has been a focus on getting students to develop a deeper conceptual understanding of the scientific method, rather than just learning the procedures.[31] This stems from evidence from the US and other Western systems that students have shallow knowledge of the scientific method and have difficulty applying their learning to new situations. This idea that students need to know why they are performing certain procedures in order to be able to use those procedures appropriately to address more complex issues is common to critical thinking frameworks in science.

In the Singapore, Hong Kong and NSW curricula there is a lot of overlap in the skills that are part of the secondary science curriculum.[32] Notably, the NSW syllabuses tend to designate which skills are and are not critical thinking, whereas the other systems profiled in this report do not. As a result, it is not always clear whether learning objectives in the Hong Kong or Singapore curriculum should be classified as critical thinking. Frameworks such as Bloom's Taxonomy can provide some hints – for example, that 'problem solving' is likely to be more linked to critical thinking than a skill like 'observing'.

However, it is probably more useful to think of all of these skills – critical thinking or not – as important to enable students to comprehensively understand and effectively engage in scientific inquiry. Therefore, it does not matter so much how the skills are classified as long as teachers are able to teach all of them effectively. For example, even though 'using apparatus and equipment' is not a critical thinking skill, it is actually very important that students learn it in order to be able to engage in scientific inquiry effectively, and thereby develop more critical thinking skills over time.

We can see that each of the skills listed for all three systems are broad (see Figure 7). They do not tell a teacher much about what she or he is supposed to be teaching. However, these are simply organising frameworks that show teachers the overarching skills that are embedded in more detail in the curriculum. For example, in Singapore, a broad skill like 'classifying' would be detailed for each unit based on the topic. In *Investigating Electricity*, students "investigate and classify a variety of materials as insulators or conductors." This skill of classification is repeated over and over while students are learning different types of knowledge. In that way, students are honing the skill of classification with different problem types.

This method of having students practise broad skills repeatedly over time is based on research on how students learn to think critically. Teachers develop critical thinking by helping students to recognise the deep structure of problems. The surface structure will differ depending on context (e.g. the topic you are teaching), but if students can

30 See for example M Bullock, B Sodian, & S Koerber, 'Doing experiments and understanding science: development of scientific reasoning from childhood to adulthood', in W Schneider & M Bullock, *Human Development from Early Childhood to Early Adulthood: Findings from a 20 Year Longitudinal Study*, New York, Psychology Press, 2009.

31 See for example: National Research Council, A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2011.

32 Noting that as curricula and syllabuses in NSW are based on the Australian Curriculum, most comments here about NSW could be generalised Australia-wide.

recognise that there are similar deep structures to very different looking problems, they will be better able to apply their skills.[33]

Figure 7: Key Science Skills NSW, Hong Kong and Singapore

NSW	Singapore	Hong Kong
Key Themes and Objectives		
Working Scientifically Through applying the processes of Working Scientifically, students use scientific inquiry to develop their understanding of science ideas and concepts, as well as the importance of scientific evidence.	**Science as an Inquiry** • Three Essential Features of Inquiry (Question, Evidence, Explain/Connect) • Taught with student-directed inquiry or teacher-guided inquiry, depending on the specific learning objective.	**Science Process Skills and Unifying Concepts**
Key Skills		
• Questioning and predicting • Planning investigations • Conducing investigations • Processing and analysing data and information • Problem solving • Communicating	**Engaging with phenomena through:** • Posing questions • Formulating hypothesis • Defining the problem • Generating possibilities • Predicting **Collecting evidence through:** • Observing • Using apparatus and equipment **Making meaning of evidence through:** • Comparing • Classifying • Inferring • Analysing • Elaborating • Verifying	• Observing • Classifying • Designing investigations • Conducting practicals • Inferring • Communicating
Notation of learning objectives as critical thinking or not?		
Yes	No	No

33 DT Willingham, 'How to Teach Critical Thinking', NSW Department of Education, 2019.

2.5.2 Examples from larger projects on defining science skills

Table 4 shows some examples of larger research projects that aim to define science skills. These projects mostly focus on comprehensive skills, but Table 4 shows the key relevant points about critical thinking.

A Framework for Science Education – National Research Council (USA)

The 2012 report, *A Framework for Science Education*[34], emerged from a project by the National Research Council in the US to update the evidence base on what a quality science curriculum should consist of. The report has had a large impact on science education around the world. Singapore and Hong Kong curriculum documents cite it, and the report laid the foundation for what became the Next Generation Science standards in the US.

The *Framework for Science Education* has three dimensions: (1) Scientific practices, (2) Cross-cutting concepts, and (3) Disciplinary core ideas. A key element is a focus on "understanding the nature and development of scientific knowledge". Engaging in the practices requires being guided by understandings about why scientific practices are done as they are—what counts as a good explanation, what counts as scientific evidence, how it differs from other forms of evidence, and so on.

34 National Research Council, A Framework for K-12 Science Education.

Table 4: Three dimensions of the *Framework for Science Education*

Scientific Practices	Cross-Cutting Concepts	Disciplinary Core Ideas
1. Asking questions	1. Patterns	1. Physical science
2. Developing and using models	2. Cause and effect: Mechanism and explanation	2. Life sciences
3. Planning and carrying out investigations	3. Scale, proportion, and quantity	3. Earth and space sciences
4. Analysing and interpreting data	4. Systems and system models	4. Engineering, technology, application of science
5. Using mathematics and computational thinking	5. Energy and matter: Flows, cycles, and conservation	
6. Constructing explanations	6. Structure and function	
7. Engaging in argument from evidence	7. Stability and change	
8. Obtaining, evaluating, and communicating information		

Source: National Research Council, A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2011.

OECD

The OECD's global education program regularly invites experts from around the world to support the development of frameworks for improving and assessing educational outcomes. A lot of the overarching findings are visible in the development of PISA, the OECD's Programme for International Student Assessment that assesses 15-year-olds' ability to use their reading, mathematics and science knowledge and skills.

PISA's science framework has three competencies:

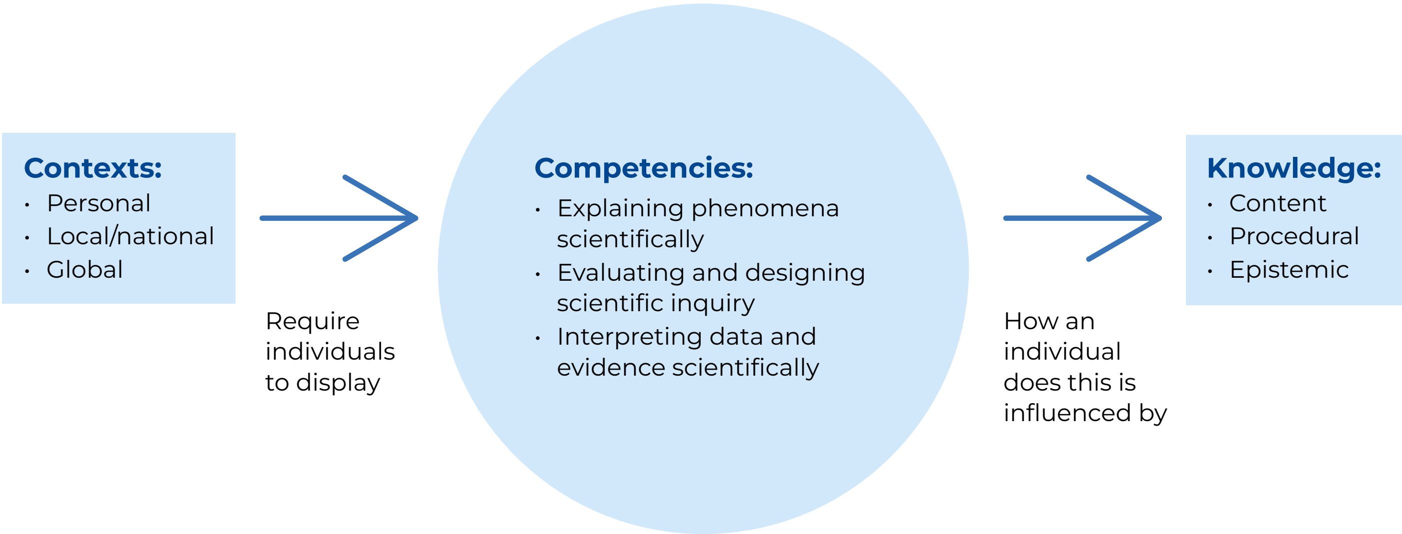
- **Explaining phenomena scientifically:** Recognising, offering and evaluating explanations for a range of natural and technological phenomena.
- **Evaluating and designing scientific inquiry:** Describing and appraising scientific investigations and proposing ways of addressing questions scientifically.
- **Interpreting data and evidence scientifically:** Analysing and evaluating data, claims and arguments in a variety of representations and drawing appropriate scientific conclusions.

Figure 8 shows how the OECD organises these three competencies within the other elements of the science domain. In addition to the three competencies are 'contexts' and 'knowledge':

- **Contexts:** Personal, local/national and global issues, both current and historical, which demand some understanding of science and technology.
- **Knowledge:** An understanding of the major facts, concepts and explanatory theories that form the basis of scientific knowledge. Such knowledge includes knowledge of both the natural world and technological artefacts (content knowledge), knowledge of how such ideas are produced (procedural knowledge), and an understanding of the underlying rationale for these procedures and the justification for their use (epistemic knowledge).
- **Competencies:** The ability to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically.

Figure 8: The three elements of the science domain according to the OECD

Source: OECD, PISA 2018 Science Framework, OECD iLibrary website, 26 April 2019.



PISA also maps the cognitive demand in different assessment items, showing how students might be able to apply knowledge and competencies to lower or high cognitive-demand situations.

- **Low demand:** Carrying out a one-step procedure, such as recalling a fact, term, principle or concept or locating a single point of information from a graph or table.
- **Medium demand:** Using and applying conceptual knowledge to describe or explain phenomena; selecting appropriate procedures involving two or more steps; organising or displaying data; or interpreting or using simple data sets or graphs.
- **High demand:** Analysing complex information or data; synthesising or evaluating evidence; justifying; reasoning given various sources; developing a plan or sequence of steps to approach a problem.

Theory on the types of science knowledge

In a 2010 summary of research on science teaching, Roberts, Gott, & Glaesser identified three distinguishable types of science knowledge. These three types of knowledge are often cited in curricula and textbooks around the world (with slight variations depending on the context):

- **Knowledge of the content of science:** facts, concepts, ideas and theories about the natural world.
- **Procedural knowledge or 'concepts of evidence':** the knowledge of the practices and concepts on which empirical inquiry is based. These include repeating measurements to minimise error and reduce uncertainty, the control of variables, and standard procedures for representing and communicating data.
- **Epistemic knowledge:** Understanding how scientific knowledge is built. This knowledge includes understanding the function that questions, observations, theories, hypotheses, models and arguments play in science; a recognition of the variety of forms of scientific inquiry; and understanding the role that peer review plays in establishing knowledge that can be trusted.

Box 3:

Digital source evaluation: applicable to both history and science teaching

Current secondary students have grown up with the Internet, and many studies show that younger people often struggle to identify true versus misleading information they find online. For example, a recent COVID-19 study found that people aged 18-25 are more likely to believe COVID-19 myths than older people.[35] In a 2016 Stanford study, 82 per cent of students couldn't tell the difference between a native advertisement (meaning paid content, such as an article paid for and/or written by a company and published in a newspaper) and genuine news article.[36] "We blame our kids for not knowing the difference between ads and news stories, but the kinds of skills we are talking about are not widely taught in schools," said the author of the study.[37]

The idea of teaching students how to evaluate digital sources applies to virtually any learning area but tends to have the most crossovers in humanities and science domains. Before the digital age, sources of information were more curated for students. For example, many students learned how to conduct research in libraries, which meant that their ability to access knowledge was generally limited to what was formally published in books or journals. Current students conduct research primarily using search engines like Google. The pages they encounter are much less likely to be from recognisable sources and more likely to contain questionable information. Therefore, teaching students digital source evaluation skills, as a component of research skills, is important to improving their long-term critical thinking.

One example of teaching students to better evaluate online sources is called lateral reading. Lateral reading is leaving a site to see what other digital sources say about it. A study found that fact-checkers, who use lateral reading in their work, were far more likely to correctly assess the legitimacy of online sources compared to professional historians or students, both groups which tended to analyse the source itself instead of leaving the source to look at other sites.[38] When students were taught to do lateral reading, they improved significantly in discerning fact from fiction on the Internet.[39]

35 B Nickel, C Bonner, & K Pickles, '[Young men are more likely to believe COVID-19 myths. So how do we actually reach them?]', *The Conversation*, 10 August 2020, accessed 13 October 2020.

36 S Wineburg, S McGrew, J Breakstone & T Ortega '[Evaluating Information: The Cornerstone of Civic Online Reasoning]', Stanford Digital Repository, 2016.

37 K Schwartz '[How to Teach Students Historical Inquiry Through Media Literacy And Critical Thinking]' *KQED*, 24 March 2019.

38 S Wineburg & S McGrew, *Lateral Reading: Reading Less and Learning More When Evaluating Digital Information*, Rochester NY, Social Science Research Network, 2017.

39 J Breakstone, M Smith, P Connors, T Ortega, D Kerr & S Wineburg, 'Lateral reading: College students learn to critically evaluate internet sources in an online course', *Harvard Kennedy School Misinformation Review*, 2017.

2.6 Critical thinking in secondary history

> History is much more than 'the past'. It is an entire practice of reading and writing of that past: sources must be gathered and interrogated, arguments must be synthesised, characters must be examined with both empathy and judgment, competing versions must be teased out, and our own approaches need to be self-consciously criticised.[40]

As with science, at the core of most research literature on critical thinking in history teaching is the idea of historical inquiry. In both science and history, what matters is not just learning the steps or procedure of inquiry in each domain but being able to deeply understand how to apply inquiry methods to novel and more complex situations to generate new knowledge. On the surface, many of the key skills in history – analysis, evaluation, posing questions – sound similar to those in science but they are executed differently and for a different purpose. As discussed in this report, historical inquiry often has a different goal than that of scientific inquiry, which means that skills learned in one area are not always easily applied in another.

For example, a skill common to both domains is analysing the credibility of the evidence. In science, it is not so important to know much about the author of a study or the source of the evidence. It is more important to look at the methodology used and understand its inherent limitations, the results and therefore the conclusions. Even when scientific papers are written by potentially biased groups (which happens often), it is still the methods and methodology that matter most in evaluating its usefulness – including how much the paper's authors attempted to control for bias.[41]

In history, knowing contextual information about the source is much more important for analysing evidence. For example, it may be quite critical to know about the dates, location, and affiliation of the author of a particular document. A key question in history teaching, as in science teaching, may be 'how reliable is this source?' In both situations, students are analysing evidence based on skills and knowledge they have learned that are applicable to that specific domain.

40 J Tosh, *Why History Matters*, Palgrave Macmillan, Basingstoke, 2008.

41 For example, many researchers use a double-blind approach to ensure they eliminate bias. This method would make a scientific paper more convincing (regardless of the research funder) as compared to a paper with a method more susceptible to the author's bias. AM Šimundić, 'Bias in Research', *Biochemia Medica* 2013, 23(1):12-15.

Box 4: Source analysis in history teaching

Wineburg (2001) demonstrated that students who lack a strong understanding of history tend to view historical sources as neutral repositories of information, and therefore see the author as unimportant. However, with the context of a base of historical knowledge, students can be taught different frameworks for analysing sources more critically.[42]

For example, VanSledright (2004) offers a four-stage model for source analysis:

1. **Identification**: Establish the nature of the source.
2. **Attribution**: The source was produced by someone at a certain time and place.
3. **Judging perspective**: The source offers a viewpoint of the past – the beliefs, values, and attitudes of the author shape the inferences that might be drawn from the source.
4. **Reliability assessment**: To what extent can and does the source further our understanding of the past? What are its strengths? What are its weaknesses?[43]

42 S Wineburg, Historical Thinking, Philadelphia: Temple University Press, 2001.

43 BA VanSledright, 'What Does It Mean to Think Historically ... and How Do You Teach It?', Social Education, 2004, 68(3):230.

Modern literature on the teaching of secondary history places greater emphasis on getting away from solely focusing on factual recall of names and dates and instead giving students more skills to understand how historical knowledge was derived (also known as 'disciplinary knowledge' – see Figure 5: Two types of knowledge in a domain). For example, teaching 'historical thinking' has become an important goal and is written about by history teaching experts across the world.[44] The authors of the Australian Curriculum: History, for example, wrote a 2020 book called *Historical Thinking for History Teachers*, which references different international approaches to teaching historical thinking.[45] Historical thinking is defined in different ways but is often related to critical thinking and historical inquiry.

44 S Wineburg, *Historical Thinking* in the US and T Allender, A Clark, & R Parkes (eds.), *Historical Thinking for History Teachers: A new approach to engaging students and developing historical consciousness 2020*, Routledge, 2020 in Australia, for example.

45 Allender et al., *History Thinking for History Teachers.*

> Historical thinking refers fundamentally to the capacity to think or reason like a historian.[46]

2.6.1 Historical thinking

Historical thinking refers fundamentally to the capacity to think or reason like a historian.[47] Yet experts also recognise that "one cannot simply replicate historians' processes in a classroom"[48] and that the teaching of historical thinking in secondary school requires the prioritisation of key skills. Sam Wineburg of Stanford's History Education Group has popularised the notion that historical thinking is 'unnatural' – meaning it is different from normal thinking.[49] For example, many in the general public may confuse being 'critical' as thinking critically. A student who reads a 1914 historical document that announces a new Captain Cook statue may be able to articulate that the document was myopic about Cook's treatment of Indigenous people. But although the student was being critical, it was not true historical thinking. By contrast, historians examining the same document might ask about the time period in which it was written, politics in that particular location, and speak to issues that may not have much at all to do with Cook as a person. To the historians, the document may be more about 1914 rather than 1770.[50] The critical process historians use for thinking about the past is what many experts mean when they refer to teaching historical thinking.

A key point in the literature about historical thinking is that it is not always obvious to teachers what teaching historical thinking looks like in practice. In a small research study, for example, US teachers were asked to come up with questions to spur students to think historically. Many devised questions with a morality lens rather than with a historical lens – for example, "Is there someone in your lifetime that is viewed more positively than he or she should be?" or "What do you consider to be noble?"[51] The Historical Association in the UK explains that these questions tend towards "moral superficiality rather than rigorous thinking".[52] The point to teaching historical thinking is that it might not always be the easiest way of thinking about the past, which is why history teaching experts believe it is so important for student learning.

There are many different frameworks for what teaching historical thinking means. Here are a few examples:

From the Australian Curriculum:

1. **Establish historical significance**: What is important about the past and why we care about certain events, trends, issues, or people.
2. **Use evidence**: How to locate, select, contextualise, and corroborate primary sources from the past and secondary accounts about the past.
3. **Identify continuity and change**: What has changed and what has remained the same over time.
4. **Analyse cause and effect**: Reason how and why certain conditions and actions led to particular consequences or events.
5. **Take historical perspectives**: Understand that people and societies think differently in different social, cultural, and historical situations.
6. **Understand the moral dimension of historical interpretations**: How our values and the values implicit in the historical narratives we encounter have consequences for people.[53]

46 Allender et al., *History Thinking for History Teachers.*

47 Allender et al., *History Thinking for History Teachers.*

48 C Counsell, 'Disciplinary knowledge for all, the secondary history curriculum and history teachers' achievement', *The Curriculum Journal*, 2011, 22(2):201-225.

49 S Wineburg, 'Unnatural and essential: the nature of historical thinking', *The Historical Association*, 2009.

50 Excerpted from a longer case study in Wineburg, 'Unnatural and essential'.

51 S Wineburg, 'Reading Abraham Lincoln: An expert/expert study in the interpretation of historical texts', *Cognitive Science*, 1998, 22(3):319-346.

52 Historical Association, 'What's the wisdom on enquiry questions?', 2020.

53 ACARA, 'Australian Curriculum: History – Structure', Australian Curriculum website, accessed 24 June 2022.

Historical Thinking Competencies in History (HiTCH project), 2015

Competencies:

1. Competence in questioning, or inquiry
2. Methodological competence
3. Orientational competence (in relation to time)
4. Disciplinary competence (in using the concepts of historical practice)[54]

Historical Thinking Project (Canada), 2006

Also known as the Benchmarks of Historical Thinking:

1. Historical significance: What is important to learn about the past?
2. Evidence: How do we know what we know about the past?
3. Continuity and change: Make sense of the complex flows of history
4. Cause and consequence: Why do events happen and what are their impacts?
5. Perspective-taking: Understand people of the past
6. Ethical dimension: How can history help us live in the present?[55]

American Historical Association, 2007

The five C's of historical thinking:

1. Concepts of change over time
2. Causality
3. Context
4. Complexity
5. Contingency[56]

2.6.2 Historical inquiry

Historical thinking is sometimes discussed as synonymous with historical inquiry, but many history teaching experts look at the historical inquiry as more of a process. It is often said that the inquiry process answers the key questions that comprise historical thinking. Structured historical inquiry is not to be confused with general references to inquiry learning that may emphasise student-led approaches. Many history teaching experts write about historical inquiry as being more teacher-led, while others explain that both student-led and teacher-led approaches are useful but for different purposes.[57] For example, students may be able to lead some elements of the inquiry process, such as designing the inquiry question itself, but teachers have to assess whether students have had enough prior skill development to do so autonomously.[58] All experts emphasise that simply giving students autonomy is not the goal for each lesson because many historical thinking skills are not intuitive. Rather, historical inquiry requires careful teacher planning and needs to be modelled to students with a variety of resources and scaffolds.

> The principle of a structured historical enquiry – often referred to as an 'Enquiry Question' – has been developed and refined by history teachers over the past 20 years or more and was, in part, developed in direct opposition to the principles of 'discovery learning' and to the assumption that pupils would become effective independent thinkers simply by being given more independence. It was also part of a reaction against de-contextualised, skill-based exercises that failed to take into account the role of knowledge in making sense of the past.
>
> An 'enquiry' in the history education community is shorthand for a sequence of lessons integrated by a direct focus on a single 'enquiry question' and within which pupils build knowledge systematically and cumulatively in order to be able to answer that question by the end of it. A well-crafted enquiry explicitly facilitates a knowledge-rich approach to history and allows the teacher to guide the pupil through complex and contrary histories rather than leaving them to reach ill-informed judgements without adequate knowledge.[59]

54 Catholic University of Eichstaett-Inglostadt, 'Historical Thinking: Competencies in History (HiTCH)', 2015.

55 Centre for the Study of Historical Consciousness, The Historical Thinking Project, 2006.

56 Andrews & Burke, 2007

57 T Allender, A Clark & R Parkes (Eds), *Historical Thinking for History Teachers: A new approach to engaging students and developing historical consciousness*, Routledge, 2020.

58 R Gilbert & B Hoepper, *Teaching Society and Environment*, Cengage Learning, 2010.

59 R Sullivan, 'DfE clarifies reference to enquiry-based learning', Historical Association, 8 August 2018.

Historical inquiry is described as including a number of skills, for example:[60]

- Asking relevant questions
- Critically analysing and interpreting sources
- Considering context
- Respecting and explaining different perspectives
- Developing and substantiating interpretations
- Communicating effectively

Singapore's Cycle of Historical Inquiry includes the following skills:[61]

- Asking guiding historical questions
- Identifying and locating relevant sources
- Constructing historical interpretations
- Evaluating sources
- Developing arguments
- Checking/reflecting on interpretations
- Presenting historical interpretations

2.6.3 Skills in NSW, Hong Kong, and Singapore

The above sections show the concepts and skills that are likely to contribute to critical thinking in history. Most fall under the umbrellas of historical thinking or historical inquiry. Historical thinking outlines more of the critical concepts (for example, 'change') and historical inquiry outlines more of the process (for example, analysing sources). However, there is overlap and the two come together in the literature to represent what is usually defined by critical thinking in the discipline.

Table 5 shows the concepts and skills outlined in the secondary history syllabuses in NSW, Hong Kong, and Singapore. These concepts and skills align with the literature, with some additional detail in the syllabuses, especially in Hong Kong, which has finer grain size to its skills list. The examples in these three systems provide another perspective on the key skills students should be learning in history, but not all of these would fall under the umbrella of critical thinking skills. For example, 'conduct oral history' in Hong Kong may be a discrete skill that students have to learn for research purposes but may not involve higher order thinking. There are similar skills in science. For example, learning how to use lab equipment may not represent critical thinking in the skill itself but it may help students to be *able to* learn critical thinking skills by allowing students to conduct quality research.

60 Allender et al., *Historical Thinking for History Teachers.*

61 Curriculum Planning and Development Division, [History Teaching and Learning Syllabuses (Lower Secondary)], Singapore Ministry of Education, 2021.

Table 5: Key History Concepts and Skills in NSW, Singapore and Hong Kong

NSW	Singapore	Hong Kong
Key Themes and Objectives		
Site studies, depth studies and associated inquiry questions	**Cycle of historical Inquiry** Sparking curiosity > Gathering evidence > Exercising reasoning > Reflective thinking	**Historical Inquiry**
Key concepts and skills		
• Continuity and change • Cause and effect • Perspectives and interpretations • Empathetic understanding • Significance • Contestability • Comprehension: chronology, terms and concepts • Analysis and use of resources • Research • Explanation and communication	• Asking questions about the events, issues, forces or developments • Comparing different aspects of the periods, events and issues studied to establish change and continuity • Examining the causes and consequences of historical events and situations • Establishing the historical significance of an event on society • Interpreting and acquiring information and evidence derived from various sources of information from a variety of media, to support an inquiry • Identifying points of view in History • Organising and communicating historical knowledge and understanding in a coherent way	• Understand the division of historical periods • Distinguish the types of sources • Describe, summarise, induce the characteristics • Connect the past with the present • Trace historical background • Analyse causes, results and impacts • Conduct oral history • Induce and infer • Trace and classify • Analyse change and continuity • Analyse the turning point of history • Analyse the importance of historical figures or understand different interpretations towards historical figures.
Notation of learning objectives as critical thinking or not?		
Yes	No	No

3 What does the evidence say about the teaching of critical thinking, particularly in science and history?

This section is organised into four categories:

1. General principles of good teaching
2. Specifics for teaching critical thinking
3. Teaching critical thinking in secondary science
4. Teaching critical thinking in secondary history

3.1 General principles of good teaching

There are some general principles of the good teaching that have a wide evidence base but may be referenced by many different terms for the same idea. For example, in the Evidence For Learning Toolkit 'metacognition' and 'self-regulation' are used interchangeably, but other researchers use 'self-regulation' to refer to slightly different skills.[58] But each summary of best teaching practices comes to similar conclusions about what works best.

The following are general principles of instruction from Rosenshine, 2012.[59] These principles are research-based and apply to all subject areas. They are not specifically about teaching critical thinking (which is covered in the next section), but they are useful in light of the fact that the research on teaching critical thinking is thin. These principles are likely to apply to all types of teaching, including the teaching of critical thinking.

58 See for example AL Duckworth & SM Carlson, 'Self-Regulation and School Success', in BW Sokol, FME Grouzet & U Muller (eds) *Self-Regulation and Autonomy*, Cambridge University Press, Cambridge, 2013, where 'self-regulation' is more about student behaviour than just student thinking skills.

59 B Rosenshine, 'Principles of Instruction: Research-based strategies that all teachers should know', *American Educator*, 2012.

Principles of instruction

1. *Begin a lesson with a short review of previous learning*: Daily review can help strengthen previous learning and lead to fluent recall (important for student cognitive load).[60]
2. *Present new material in small steps with student practice after each step*: Teachers can present new skills (including critical thinking skills) in steps and model, for example with a think aloud, before student practice.
3. *Ask a large number of questions and check the responses of all students*: Questions allow the teacher to assess learning, and the most effective teachers also ask students to explain the process for how they answered the question.
4. *Provide models*: Models and worked examples can speed up learning. A worked example is a step-by-step example of how to approach a task or problem. Modelling means teachers acting out or talking through the steps of a given task.
5. *Guide student practice*: This is important for new learning – students need a lot of rehearsal, rephrasing, elaborating, and summarising to store new skills in long-term memory. Teachers can help by asking questions during student practice to ensure students are understanding the given task.
6. *Check for student understanding*: Checks can help teachers make sure students are not developing misperceptions. Teachers can use a variety of methods, including asking students to explain ideas or summarise learning.
7. *Obtain a high success rate*: Research suggests that the optimal success rate is 80 per cent, meaning that students are learning but they are also being challenged.
8. *Provide scaffolds for difficult tasks*: Provide temporary supports for new and difficult tasks. Scaffolds may be tools, models, cue cards, or checklists.
9. *Require and monitor independent practice*: Students need extensive, successful, independent practice for skills and knowledge to become automatic.
10. *Engage students in weekly and monthly review*: The more students rehearse and review information, the stronger they develop their connections between learnings.

3.2 Specifics for the teaching of critical thinking

Research on the teaching of critical thinking is still emerging, and there is not a lot of empirical evidence on what works best. However, in many areas, there is enough substantial evidence to allow researchers to generally agree on some advice for teachers. Below, we outline some of the key pieces of research on teaching practices that affect student learning of critical thinking.

3.2.1 Building on domain knowledge

Research has shown that being able to apply critical thinking skills requires domain expertise.[61] In other words, the transferability of skills across domains is limited without knowledge of the specific subject area. It is therefore important that teaching focuses on knowledge, and the teaching of knowledge, just as much as (or more than) on skills. This approach does not necessarily advocate rote learning of facts – domain knowledge can be taught in many different ways, including through an inquiry process. However, the important thing is to prioritise domain knowledge in instruction, meaning that teachers aren't considering content secondary to skills. Teachers who prioritise content are not filling lessons with facts – instead, when they are planning how to teach a skill, they are also considering what content is most important to teach alongside it.

Problems can arise if a skill (such as research skill) is prioritised over knowledge (such as the topic students are researching). In this scenario, teachers can unintentionally use tasks or articles for in-class reading in which the content of the task is not connected to curriculum or prior learning. For example, teachers may find a digital resource that provides an example of scaffolded steps for students to analyse a news article. However, learning is much enhanced if the content of the article is chosen specifically to connect to other learning, rather than just being a random topic used to illustrate the skill.

This concept is often referred to as a 'knowledge-rich curriculum.'[62] It means that students are able to more easily make connections and deepen their learning if the content is rigorously and strategically taught in line with skills. There is evidence that this improves students' critical thinking skills in a given domain. For example, reading comprehension is generally

60 Centre for Education Statistics and Evaluation, 'Cognitive load theory: Research that teachers really need to understand', NSW Department of Education, 2017.

61 Centre for Education Statistics and Evaluation, 'General capabilities: A perspective from cognitive science', NSW Department of Education, 2019.

62 ED Hirsch, *Why knowledge matters: rescuing our children from failed educational theories*, Harvard Education Press, Cambridge MA, 2016; G Houchens, Why Knowledge Matters, Part II: Strengthening standards with a content-rich curriculum, 2017.

seen as a type of critical thinking skill, but evidence shows that it cannot be easily taught solely in English class. This is because students' reading comprehension skills depend heavily on the background knowledge they have about the topic they are reading about.[63] In history class, students will struggle more with reading about civilisation or event they have never learned about before, regardless of their prior reading ability.

It is, therefore, useful to have instructional resources that carefully integrate the teaching of knowledge and skills. Instead of a research activity that gets students to research a topic of their choice in the hopes of developing general research skills, a quality instructional resource will have a specific knowledge learning objective alongside any skill objective. The knowledge objectives will be carefully constructed so that all students get an equal opportunity to learn about the same key content areas as every other student, ideally via the system's curriculum.[64]

Figure 9: Willingham, 2019 Practices for Critical Thinking

Domain knowledge	Practice with the skill	Metacognitive skills
• Content coverage is critical • Necessary to reduce cognitive load	• Seeing many examples of the same deep structure with different surface structures • It is about quantity of practice • Domain-specific (skills are not general)	• Cues to remember *when* to think • Recognising problems with the same deep structure when it isn't obvious

3.2.2 Recognition of cognitive load theory

Cognitive load theory includes two ideas: (1) there is a limit to how much new information the human brain can process at one time and (2) more information can be stored in long-term memory. The aim of cognitive load research is therefore to develop instructional techniques that reduce strain on working memory by deliberately storing lower-order information into long-term memory, in order to allow the brain to focus on more challenging tasks.[65]

Instructional materials designed to accommodate this theory would both include explicit teaching and sequence learning in a way that ensures the lower-order information needed for more complex work is taught and practised well before students are independently working on complex problems. This approach does not mean that complex inquiry questions cannot be introduced early to students, or that only older students can engage in complex thinking. Instead, the theory is proposing the design of instruction to give more support to students early on, when they are learning new concepts. Student-led work on new complex topics should be introduced later.

A good instructional tool (that would be included in a well-designed resource) is the worked example. A 'worked example' is a problem that has already been solved for the learner, with every step fully explained and clearly shown. By contrast, unguided problem-solving places a heavy burden on working memory, and the student will not learn as much if this is the case.

A side note on the worked example: the rationale behind why this works for children's learning is the same rationale for why comprehensive instructional materials are necessary for teachers. Many teachers are cognitively overloaded, and therefore not able to deeply learn and improve. But quality instructional materials essentially act as worked examples for teachers – they show teachers exactly how a great lesson works, they have explanations of why certain elements of the lesson were chosen, and they allow teachers to direct trial the lesson with students. As with students, teachers who have more mastery of quality lesson planning from the worked examples are then able to move to more self-created resources.

63 MG Levine & GJ Haus, 'he Effect Of Background Knowledge On The Reading Comprehension Of Second Language Learners', *Foreign Language Annals*, 1985, 18(5):391-397; A Talwar, EL Tighe, & D Greenberg, ' Augmenting the Simple View of Reading for Struggling Adult Readers: A Unique Role for Background Knowledge', Scientific Studies of Reading, 2018, 22(5): 351-366

64 N Wexler, *The Knowledge Gap*, Avery, 2019.

65 Centre for Education Statistics and Evaluation, 'Cognitive Load Theory'.

3.2.3 Metacognitive skills

Metacognition is "thinking about thinking."[66] Some researchers view metacognition as a form of critical thinking because it involves knowing the strategies to solve a problem and how to make decisions about deploying these strategies. Metacognition might also be seen as a supporting condition for critical thinking because monitoring the quality of one's thoughts helps ensure high-quality thinking.[67] Therefore, instructional materials that include strategies for student metacognition and reflection will likely improve critical thinking.

Table 6: Example recommendations for teaching metacognitive skills from the Evidence for Learning Toolkit

Recommendation	Detail
Recommendation 1	Teachers should acquire the professional understanding and skills to develop their students' metacognitive knowledge.
Recommendation 2	Explicitly teach students metacognitive strategies, including how to plan, monitor, and evaluate their learning.
Recommendation 3	Model your own thinking to help students develop their metacognitive and cognitive skills.
Recommendation 4	Set an appropriate level of challenge to develop students' self-regulation and metacognition.
Recommendation 5	Promote and develop metacognitive talk in the classroom.
Recommendation 6	Explicitly teach students how to organise, and effectively manage their learning independently.
Recommendation 7	Schools should support teachers to develop their knowledge of these approaches and expect them to be applied appropriately.

Source: *Education Endowment Foundation, Teaching and Learning Toolkit – Australia*, 2015

66 NSW Department of Education, 'Metacognition', Education for a Changing World website 2021, accessed 23 June 2022.

67 ER Lai, 'Critical Thinking: A Literature Review', Pearson, 2011.

3.2.4 Explicit teaching

> Explicit teaching practices involve teachers clearly explaining to students why they are learning something, how it connects to what they already know, what they are expected to do, how to do it and what it looks like when they have succeeded. Students are given opportunities and time to check their understanding, ask questions and receive clear, effective feedback.[68]

There is ample evidence that explicit teaching produces higher student learning outcomes. This is true for all instruction, but there is also evidence that explicit teaching of critical thinking skills is likely to lead to greater learning. For example, Abrami et al. (2008) examined 177 studies on the effects of instructional interventions on students' critical thinking skills. The researchers found the best results were achieved with a mixed approach, in which explicit critical thinking instruction was integrated with explicit content instruction.[69] Many other researchers have stated that critical thinking skills are unlikely to develop in the absence of explicit instruction.[70]

As the definition above shows, this approach enables teachers to clearly explain why students are learning a certain skill, and how they might apply that skill in different ways over time. Teachers may include certain scaffolds when they are first teaching the skill to make it more explicit, and students can become more autonomous once they have mastered the skill. For example, when teaching students how to make a well-reasoned argument, teachers might explicitly teach underlying skills such as using evidence to justify a point. To show explicitly to students how those different pieces make up an argument, teachers might provide a worksheet with instructional text such as 'your opinion' and 'the evidence to justify your opinion'. When students have more mastery, teachers may then take the worksheet away.

3.2.5 Structured questioning

There is good evidence that structuring questions to encourage student thinking can help build critical thinking skills.[71] Quality instructional materials will help teachers to take this approach by anticipating student thinking and outlining several lines of inquiry teachers can use for students at different learning levels. Questions can be formally built into assessments, but they can also be used in class discussions or informal talks with students. Many quality instructional materials will include sample questions teachers can use with various student activities. For example, during a science experiment, a teacher may deploy structured questions as she walks around the room to get students to think more deeply about what they are experiencing through their work. With good use of structured questions, teachers do not have to design specialised tasks just to teach critical thinking. They can use any lesson plan and use structured questions to drive deeper student thinking.

68 Centre for Education Statistics and Evaluation, 'What works best: 2020 update', NSW Department of Education, 2020.

69 P Abrami, R Bernard, E Borokhovski, A Wade, M Surkes, R Tamim & D Zhang, 'Instructional Interventions Affecting Critical Thinking Skills and Dispositions: A Stage 1 Meta-Analysis', *Review of Educational Research*, 2008, 78:1108-1134.

70 R Case, 'Bringing Critical Thinking to the Main Stage', Education Canada, 2005, 45; PA Facione, 'Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction. Research Findings and Recommendations', American Philosophical Association, 1990; DF Halpern, ' Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring', American Psychologist, 1998, 53(4):449-455; Richard Paul, 1992; D Willingham, 'How to teach critical thinking', NSW Department of Education, 2019.

71 Next Generation Science Standards, Read the Standards, 2015.

Excerpt of Next Generation Science Standards Recommendations (US resource)

Help students build explanations by asking and answering deep questions.

When students have acquired basic knowledge about a particular topic of study and are ready to build a more complex understanding of a topic, we recommend that teachers find opportunities to ask questions and model answers to these questions, in order to help students build deep explanations of key concepts. By deep explanations, we mean those that appeal to causal mechanisms, planning, well-reasoned arguments, and logic. Examples of deep explanations include those that inquire about causes and consequences of historical events, motivations of people involved in historical events, scientific evidence for particular theories, and logical justifications for the steps of a mathematical proof. Examples of the types of questions that prompt deep explanations are why, why-not, how, what-if, how does X compare to Y, and what is the evidence for X? These questions and explanations occur during classroom instruction, class discussion, and during independent study.

Source: Next Generation Science Standards, nextgenscience.org, n.d., accessed 25 May 2022.

3.2.6 Practice

Critical thinking skills, like all skills, require extensive practice. Some research describes the need for long-term, repeated exposure to problems with the same deep structure but different surface structure.[72] For example, in maths the deep structure might be the mathematical concept used to solve the problem, but the surface structure might be different scenarios in word problems, which require the re-ordering of steps to solve the problem.

The concept of deliberate practice is also linked to critical thinking teaching research. Deliberate practice is a specific type of practice that research has shown helps people to become experts. Most deliberate practice research is about specific skills like playing chess, tennis or even identifying wine.[73] Some research has shown that deliberate practice can support specific critical thinking skills in science learning as well.

In one study, for example, students in a physics class were asked to make repeated data comparisons based on instructions. The instructions were slowly phased out during the course to allow students more independence. After the instructions had been removed, students in the experimental condition were 12 times more likely to spontaneously propose or make changes to improve their experimental methods than a control group who performed traditional experimental activities without repeated practice. The students in the experimental condition were also four times more likely to identify and explain the limitations of their data. Students in the experimental condition also showed much more sophisticated reasoning about their data.[74]

Deliberate practice is not just about an individual student practising on her own — it involves teachers (or peers) providing regular feedback so that students can improve. In alignment with the general principles of good teaching outlined above by Rosenshine, 2012, teachers can support deliberate practice by providing models and worked examples. They can also break larger tasks into smaller steps and give students feedback on each specific step to make sure they are on the right track and continuously improving.

3.3 Teaching critical thinking in secondary science

Above, we have listed the features of quality resources for teaching critical thinking in general. This section looks at a few common approaches that are specific to teaching critical thinking in secondary school science. These approaches may be detailed in resources provided to teachers. For almost all the most commonly cited practices linked to critical thinking skills, the evidence is very limited or very mixed. But teachers can still benefit from trialling these practices and collecting their own evidence in their classrooms about whether student critical thinking skills improve over time.

3.3.1 Focus on student thinking, regardless of the mode of instruction

There is evidence that the mode of instruction – teaching from a textbook versus teaching with 'hands on' methods, for example – matters less for developing critical thinking skills in science than

72 Willingham, 'How to Teach Critical Thinking'.

73 KA Ericsson, M Prietula, & ET Cokely, 'The Making of an Expert ', *Harvard Business Review*, July-August 2007.

74 NG Holmes, CE Wieman, & DA Bonn, 'Teaching critical thinking', Proceedings of the National Academy of Sciences, 2015, 112(36): 11199–11204.

the ability of teachers to probe student thinking.[75] Two styles of teaching – learning at a desk and learning more actively – can both be done well or poorly. A hands-on teacher can merely ask students to follow step-by-step instructions without pushing them to think through why they are doing these steps. Meanwhile, a textbook teacher can ask fabulous questions that play a central role in taking students to higher levels of thinking. For example: Why is the study we designed the right study to answer that question? Why does the data support your idea?[76]

Many researchers see teacher questioning as the pivotal skill to support critical thinking in science class.[77] Similarly, teachers can set up learning experiences to elicit student questions for peers or for the teacher. An environment that encourages open questions – from teacher and student – helps students to express their ideas, explore, take risks, and share successes and failures. Students also need to be given time to think and to be encouraged, through thought-provoking questions, to discuss and to reflect.[78]

3.3.2 Active learning

Many science curricula around the world recommend active learning. For example, the NSW Science Syllabus 7-10 encourages 'active' engagement in scientific inquiry and the Singapore Science (Lower Secondary) Syllabus includes 'Strategies for Active and Independent Learning (SAIL)'.

Active learning is a broad concept that is based on constructivist learning theory[79] and therefore shares characteristics with inquiry learning and student-directed learning. Teachers who employ active learning often encourage reflection, support peer interaction, rethink the physical environment, and enhance understanding with technology, among other practices.[80] The concept is very broad and may have varied implementation in a science classroom. Specific methods may include guided inquiry learning, case-based teaching, problem-based learning, and flipped classrooms.[81]

The few systematic reviews and metanalyses of active learning in science teaching find there is uneven support for active learning; they also acknowledge that varying definitions of the concept limit what can be ascertained from the research. Prince, 2004 tried to separate out some of the effects of individual components of active learning and found that these elements were best supported: cooperative learning, small group instruction, and explicit instruction in problem solving. But other components, like self-directed learning, had negative effects.[82] A review of the evidence base by Michael, 2006 found evidence that active learning is more effective than passive learning but also found: "There is no single definitive experiment to prove this, nor can there be given the nature of the phenomena at work, but the very multiplicity of sources of evidence makes the argument compelling."[83]

Many studies on the effectiveness of active learning come from higher education because there has been a movement in universities to use new pedagogies to encourage more enrolment in sciences. But it is not clear how much findings about students in higher education can translate to secondary students. After all, the latter generally have less knowledge and lower levels of skill than do tertiary students, a difference that might bear directly on the effectiveness of active learning. Even within higher education, there is wide disagreement on whether active learning is truly supported by evidence.[84] One study found that university students learned more from active learning yet felt as if they had learned less than with traditional teaching modes.[85] This finding suggests that teachers and students might believe the experience of active learning is not working, when in fact it is.

Most literature on active learning emphasises that it is difficult for teachers and students to

75 MA Cannady, P Vincent-Ruz, JM Chung, & CD Schunn, 'Scientific sensemaking supports science content learning across disciplines and instructional contexts', *Contemporary Educational Psychology*, 2019, 59:101802

76 J Barshay, 'A study on teaching critical thinking in science', *The Hechinger Report*, 13 January 2020, accessed 13 October 2020.

77 LF Santos, 'The role of critical thinking in science education', *Journal of Education and Practice*, 2017, 15 for example reviews the existing literature and finds that questioning is "regarded among the most powerful tools".

78 RM Vieira, C Tenreiro-Vieira, & IP Martins, Critical Thinking: Conceptual Clarification and Its Importance in Science Education *Science Education International*, 2011, 22(1), 43–54.

79 Constructivism is 'an approach to learning that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner' according to SN Elliott, *Educational Psychology: Effective Teaching, Effective Learning*, McGraw-Hil, 2000.

80 JJ Mintzes & EM Walter, *Active Learning in College Science: The Case for Evidence-Based Practice*, Springer, 2020.

81 N Zepke & L Leach, 'Improving student engagement: Ten proposals for action', *Active Learning in Higher Education*, 2010, 11(3), 167–177.

82 M Prince, 'Does Active Learning Work? A Review of the Research', *Journal of Engineering Education*, 2004, 93(3), 223–231.

83 J Michael, 'Where's the evidence that active learning works?' *Advances in Physiology Education*, 2006, 30(4), 159–167.

84 Mintzes & Walter, *Active Learning in College Science*.

85 L Deslauriers, LS McCarty, K Miller, K Callaghan, & G Kestin, 'Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom', *Proceedings of the National Academy of Sciences*, 2019, 116(39), 19251–19257.

switch to new teaching and learning practices. Therefore, teachers need a lot of support, including professional learning and instructional resources, to understand how to make active learning effective.

3.3.3 Inquiry

Inquiry is currently a popular pedagogy in secondary school science, and science educators around the world routinely promote the benefits of inquiry-based instruction as "best practice" for fostering students' interest and understanding.[86] Inquiry is often prescribed for helping students to gain higher order thinking skills, including critical thinking skills. Inquiry-based teaching and learning, however, can be built on a wide range of practices, from collaborative small group work to discovery learning to hands-on or practical work. In science education, an inquiry has often been seen as including "student-centred interactions, student investigations and hands-on activities, and focus on models or applications in science".[87] Inquiry teaching and learning can also be confused with learning about the nature of the *scientific inquiry*, which can take many different forms in teaching but often overlaps with an inquiry as a pedagogy.

Despite the prevalence of inquiry as a pedagogy across the Western world, the evidence on its effects is mixed. In general, it appears that inquiry improves student learning and engagement, but only if it is used carefully and sparingly in science classrooms. Below is a more detailed summary of the evidence.

Many studies show positive effects of inquiry teaching practices in science

Inquiry has been shown to be effective in supporting students to engage with science.[88] Students undertaking experimental work in science class is important and can support students' skill acquisition, learning, and interest in science.[89] With appropriate guidance from the teacher, inquiry-based instruction has been shown to support students' science achievement in many contexts.[90]

Other studies show that too much inquiry (especially when student-led) will hinder learning

In international surveys, students who report the highest frequencies of inquiry-based activities consistently rate at the lower levels of scientific literacy. Generally, evidence indicates a negative association between the frequency of inquiry-based activities and students' scientific literacy.[91]

Researchers have made the case that, in general, minimally guided instruction is less effective and efficient than teacher-led practices.[92] A 2016 meta-analysis of inquiry-based learning reported that "larger effect sizes were associated with more specific types of teacher guidance,"[93] while a 2012 meta-analysis found that "studies involving teacher-led activities had mean effect sizes about .40 larger than those with student-led conditions."[94]

Similarly, research has shown that "hands on" inquiry practices in which students conduct their own experiments lead to less learning than if students were to receive direct instruction and see a demonstration of the same experiment.[95] One study concluded: "We found not only that many more children learned from direct instruction than from discovery learning, but also that when asked to make broader, richer scientific judgments, the many children who learned about experimental design from direct instruction performed as well

86 L Rennie, *Evaluation of the science by doing stage one professional learning approach 2010*. Canberra: Australian Academy of Science, 2010.

87 S Areepattamannil, 'Effects of Inquiry-Based Science Instruction on Science Achievement and Interest in Science: Evidence from Qatar', *The Journal of Educational Research*, 2012, 105(2), 134–146.

88 A McConney, MC Oliver, A Woods-McConney, R Schibeci, & D Maor, 'Inquiry, engagement, and literacy in science: a retrospective, cross-national analysis of PISA 2006', *Science Education*, 98(6).

89 S Sjøberg, 'The power and paradoxes of PISA: Should Inquiry-Based Science Education be sacrificed to climb on the rankings?', *Nordic Studies in Science Education*, 2018, 14(2), 186–202.

90 DD Minner, AJ Levy, & J Century, 'Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002', Journal of Research in Science Teaching, 2010, 47(4), 474–496.

91 M Oliver, A McConney, & A Woods-McConney, 'The Efficacy of Inquiry-Based Instruction in Science: a Comparative Analysis of Six Countries Using PISA 2015', Research in Science Education, 2021, 51, 595–616.

92 PA Kirschner, J Sweller, & RE Clark, 'Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching', *Educational Psychologist*, 2006, 41(2), 75–86.

93 AW Lazonder & R Harmsen, 'Meta-Analysis of Inquiry-Based Learning: Effects of Guidance', *Review of Educational Research*, 2016, 86(3), 681-718.

94 EM Furtak, T Seidel, H Iverson & DC Briggs, 'Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis', *Review of Educational Research*, 2012, 82(3): 300-329.

95 L Zhang, '"Hands-on" plus "inquiry"? Effects of withholding answers coupled with physical manipulations on students' learning of energy-related science concepts', *Learning and Instruction*, 2019, 60, 199–205.

as those few children who discovered the method on their own.[96]

In summary, inquiry can be helpful but has to be used carefully

According to survey data from the OECD, Australian secondary science teachers already use higher-than-average amounts of inquiry teaching practices than do other systems.[97] The question, then, is not whether to implement inquiry-based pedagogy (since it seems to already exist in classrooms), but how to improve its use for the purposes of teaching critical thinking. One researcher summarised the evidence: "Just like Goldilocks, there may be a level of use that is not too much and not too little, but just right."[98]

PISA data suggest that, on average, the strongest scientific literacy performance is associated with students who report they experience inquiry practices in some lessons. Students reporting inquiry activities in most or all lessons achieve considerably lower scientific literacy, on average.[99] However, students who report no inquiry activities also show lower learning. A small amount of inquiry practices might help to lower the cognitive load by allowing students to learn from direct instruction most of the time.[100] PISA data also show that inquiry practices, such as drawing conclusions from data, are more effective for learning whereas students designing an investigation or raising their own questions lead to lower levels of learning.[101] Therefore, science teachers may have to be most cautious when asking students to lead inquiry practices.

3.3.4 Responding to students' pre- and misconceptions

Teachers can support critical thinking by challenging students' thinking. They can explicitly tackle student preconceptions and misconceptions about different topics in science.[102] Although misconceptions generally pose obstacles to learning, they also offer some value to the learning experience. The first step for teachers is to find out, through assessments such as quizzes or other tasks that elicit student thinking, what preconceptions students may hold. A categorisation or sorting task may show how students are thinking about various concepts and how they fit (or do not fit) together.[103]

Instructional materials that outline common student pre-conceptions can be helpful for teachers. These resources may also provide options for how teachers can address different pre-conceptions.

3.4 Teaching critical thinking in secondary history

This section examines the types of teaching practices that may help to develop critical thinking skills in secondary history. Resources to support teachers may include information about what these practices look like in the classroom.

3.4.1 Depth studies

In 1972, a history teaching project for Years 9–11 was trialled in 32 British schools. The goal was to develop historical thinking skills by looking at primary sources in-depth studies. The project was considered successful initially and, with some adjustments, influenced the development of the UK history curriculum.[104] It opened teachers to the idea that history teaching should not lead to a single inevitable conclusion, but rather to more open-ended explanations based on disciplinary methodology. It also emphasised the role of inquiry-based teaching. The project widely influenced thinking about history teaching, including in Australia.[105]

In the 1970s and 1980s, ideas such as inquiry-based teaching and depths studies were becoming more common around the world. Many teachers found that the new ways of teaching worked well, but many others struggled to implement them in practice. There were fears about 'reductive' approaches and particularly of growing distortions

96 Klahr & Nigam, 'The Equivalence of Learning Paths in Early Science Instruction: Effects of Direct Instruction and Discovery Learning', *Psychological Science*, 2004, 15(10), 661–667.

97 T Mostafa, A Echazarra, & H Guillou, 'The science of teaching science: An exploration of science teaching practices in PISA 2015'. OECD, Paris, 2018.

98 Oliver et al., 'The Efficacy of Inquiry-Based Instruction in Science'.

99 F Jiang & WF McComas, 'The Effects of Inquiry Teaching on Student Science Achievement and Attitudes: Evidence from Propensity Score Analysis of PISA Data', *International Journal of Science Education*, 2015, 37(3), 554–576; Oliver et al., 'The Efficacy of Inquiry-Based Instruction in Science'.

100 Zhang, '"Hands-on" plus "inquiry"?'

101 Jiang & McComas, 'The Effects of Inquiry Teaching'.

102 J Osborne, 'Teaching Scientific Practices: Meeting the Challenge of Change', *Journal of Science Teacher Education*, 2014, 25(2), 177–196.

103 J Luciarello & D Naff, 'How do my students think: Diagnosing student thinking', American Psychological Association, 2015, accessed 13 October 2020.

104 Allender et al., *Historical Thinking for History Teachers.*

105 Allender et al., *Historical Thinking for History Teachers.*

in the work of analysing sources. For example, one report identified problems with teachers "encouraging the mistaken view that a source can be reliable in itself rather than reliable for something."[106]

There is very little evidence on the effectiveness of depth studies, which are used today in various forms for teaching history, including in the NSW Curriculum. A substantial amount of evidence finds teaching for depth versus breadth is more effective for student learning, especially for higher order thinking skill development.[107] However, this research is not available specifically for history teaching. It may be worth generalising this evidence to assume that similar principles apply to history and that organising instruction around depth studies is a good idea.

The effectiveness of depth studies is likely to depend a great deal on how they are taught – what probing questions teachers ask and what scaffolds they provide to support student learning, for example. Depth studies are compatible with some of the approaches listed in this section, most of which could be combined in a given teaching unit. Teaching resources, therefore, might be useful to help teachers understand how to make depth studies most effective for developing student critical thinking skills.

3.4.2 The inquiry question

First explicitly stated by Gorman (1998), it was developed into a set of working principles by Riley (2000) and later Byrom and Riley (2003).

The inquiry question is a key component of historical inquiry. It enables teachers to plan a lesson or unit, and it is meant to both capture students' interest and connect their learning from one topic to the next. The right inquiry experience will help students to think more deeply because they will not be able to just 'google' a simple answer or find it in a textbook. As with depth studies, there is little to no evidence on whether inquiry questions help students learn. But they may be a useful way of organising instruction and can be combined with other methods, such as depth studies.

In the 1990s and 2000s, the concept of an inquiry (or 'enquiry') question became more prevalent in history teaching.[108] The idea is to end each lesson or unit with a culminating question. An inquiry question is not associated with the process of student-led inquiry as it is usually more teacher-driven.[109] It seeks to engage students in deeper thought about the lesson rather than just seeking easy answers. The lesson may conclude with various 'answers' to the question expressed in various forms – essay or role play, for example.[110] The use of inquiry questions has become a tool for teachers to link substantive knowledge and critical thinking.[111] Inquiry questions have become popular around the world, with one researcher describing them as 'the new orthodoxy.'[112] The inquiry question approach builds on depth study methods from the 1970s and 1980s, but focuses less on analysis of primary sources as the main pedagogy.

Instructional resources can help teachers to develop inquiry questions that will lead to deeper student engagement and thinking. For example, the Historical Association in the UK provides a guide to inquiry questions in history, with some examples of 'pitfalls' to avoid. This type of specific guidance may help teachers to adapt their practice.

106 *D Shemitt*, Adolescent Ideas about Evidence and Methodology in History, in *The History Curriculum for Teachers*, The Falmer Press, London, 1987.

107 MS Schwartz, PM Sadler, G Sonnert, & RH Tai, 'Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework', *Science Education*, 2009, 93(5), 798–826.

108 M Gorman, 'The "structured enquiry" is not a contradiction in terms: focused teaching for independent learning', Historical Association, 9 September 1998.

109 C Counsell, ' Disciplinary knowledge for all, the secondary history curriculum and history teachers' achievement', The Curriculum Journal, 2011, 22(2): 201-255.

110 J Byrom & M Riley, 'Professional wrestling in the history department: a case study in planning the teaching of the British Empire at Key Stage 3', Historical Association, 8 December 2008.

111 Counsell, 'Disciplinary knowledge for all'.

112 C Husbands, A Kitson, & A Pendry, *Understanding History Teaching: Teaching and Learning about the Past in Secondary Schools*, McGraw-Hill Education, 2003.

Box 5:
Historical Association (UK) – inquiry question 'pitfalls'

1. **Don't treat your inquiry question like a chapter heading**: Instead, think of the question as a way to drive student learning. At the end of each lesson, students can reflect on what they have just learned: Has it confirmed their initial hypothesis? Or has it complicated the picture, challenging over-simplistic assumptions?
2. **Don't create separate 'inquiry questions' for every lesson**: Sub-questions can be used to indicate the focus of each lesson, but don't confuse the inquiry question with the sub-questions that are intended to serve it.
3. **Don't be deceived by 'dodgy' questions**: 'Dodgy' inquiry questions are those that might work to capture pupils' interest but fail the test of historical validity. Asking: 'Was the Treaty of Versailles fair?' will almost inevitably lead to superficial or anachronistic judgements in response to the moral question posed. Nurture the historical, contextualised understanding that you need by asking, much more precisely, "Why did some people think that the Treaty of Versailles was not 'fair'?"
4. **Not all inquiry questions need to involve the use of sources**: Developing pupils' understanding of how historical knowledge depends on using sources to develop and defend claims about the past. But pupils don't need to use sources in every lesson, or in relation to every question. Inquiries involve the normal range of teaching resources and activities – textbooks, role-plays, extended sources, reading, story etc. – all of which are used to provide evidence for building, testing and revising hypotheses.

Source: Historical Association, 'What's the Wisdom on Enquiry Questions?', Teaching History, 27 March 2020.

3.4.3 Connections between second-order concepts and content

History curricula across many systems share similar second-order concepts, including cause, change and historical significance, that are essential to the practice of history. Literature on history teaching emphasises that teachers can help students to notice that these concepts re-occur throughout lessons involving different content. Teachers connecting ideas across diverse content aligns with the research on how to teach critical thinking. For example, Willingham, 2019 states that critical thinking involves practising the same deep structure on multiple different surface structures, and recognising when a new problem actually has the same deep structure as learned before. Similarly, the literature on history teaching emphasises how teaching through historical inquiry can allow students to practise the repetition of second-order history concepts, thereby improving their critical thinking:

> They see the surface details and think each new topic is different because it features new or mostly new names, dates, places, etc. This camouflage prevents students realising that they can use what they've learned before to help them with a new topic.[113]

The literature recommends that teachers take care in using depth studies (or their equivalent) to organise teaching without being explicit about how each depth study is connected to the last: "We need…pupils to move out from the particular, to see patterns and connections across time and place, to get to grips with big historical issues."[114]

113 I Dawson, 'Why is Historical Enquiry important?', Thinking History, 2009.

114 M Riley, 'Beyond a superficial scamper', *Times Educational Supplement*, 1996.

3.4.4 Reading Like a Historian skills

There are very few studies of specific methods for teaching critical thinking in history, but one recent method contains a small amount of promising evidence.

A Stanford University project, Reading Like a Historian, has expanded on the ideas of historical thinking and historical inquiry to propose specific reading skills that should be taught to secondary students in order to improve their critical thinking and historical thinking skills. The project offers teachers free lessons and assessments on its website. These resources, developed by the Stanford History Education Group led by Sam Wineburg, have been downloaded more than nine million times.[115] Helpfully, the Reading Like a Historian resources have been tested in different experiments so there is evidence of their impact on student learning. Yet while the studies are promising, they are still very limited.

A 2012 US study with 236 secondary school students in five schools used a quasi-experimental method to analyse student learning in terms of (a) students' historical thinking; (b) their ability to transfer historical thinking strategies to contemporary issues; (c) their mastery of factual knowledge; and (d) their growth in general reading comprehension. The results showed significant positive effects for all four outcomes.[116] A 2016 case study found that the Reading Like a Historian resources improved teacher instruction, but that instruction quality was still limited by the teacher's lower level subject matter and pedagogical content knowledge.[117] The resources also include sample assessments that are designed to be better than traditional assessments in measuring student learning of historical thinking skills. A 2018 validity study found that the new History Assessments of Thinking (HATs) better reflected student proficiency in historical thinking than their multiple-choice counterparts.[118]

Reading Like a Historian was originally built on the concept of a 'document-based lesson' that targeted discrete strategies of historical reading to enable students to engage in historical inquiry with sources.[119] The instructional resources are meant to support teachers in engaging students in historical inquiry, but this approach is not linked to *inquiry learning* practices. In fact, the creators of Reading Like a Historian wanted to expressly maintain the traditional roles of students and teachers (such as lecture, recitation, seatwork, group-work, whole-class discussion) in an effort to not overwhelm teachers with the changes they would be making to instruction. The creators developed the program partly because of the perceived failures they found in student-led inquiry practices.

The Reading Like a Historian resources outline a repeatable sequence that engages students in a process of historical inquiry. The resources include classroom-ready materials and activities that combine the teaching of content knowledge and disciplinary inquiry. Whereas in traditional history classrooms, students may have been expected to accept and memorise an established historical narrative from a single text (typically, the classroom textbook), students in Reading Like a Historian lessons are asked to interrogate, then reconcile, the historical accounts in multiple texts in order to arrive at their own interpretations.

115 Stanford History Education Group, '[History of SHEG]', n.d.

116 Avishag Reisman, ' Reading Like a Historian: A Document-Based History Curriculum Intervention in Urban High Schools', *Cognition and Instruction*, 2012, 30(1):86-112.

117 A Reisman & B Fogo, 'Contributions of educative document-based curricular materials to quality of historical instruction', *Teaching and Teacher Education*, 2016, 59:191-202.

118 M Smith, J Breakstone, & S Wineburg, 'History Assessments of Thinking: A Validity Study', *Cognition and Instruction*, 2019, 37(1):118-144.

119 A Reisman, 'The "Document-Based Lesson": Bringing disciplinary inquiry into high school history classrooms with adolescent struggling readers, *Journal of Curriculum Studies*, 2012, 44(2):233-264.

Table 7: Reading Like a Historian Framework

Historical Reading Skills	Questions	Students should be able to…	Prompts
Sourcing	• Who wrote this? • What is the author's perspective? • When was it written? • Where was it written? • Why was it written? • Is it reliable? Why? Why not?	• Identify the author's position on the historical event. • Identify and evaluate the author's purpose in producing the document. • Hypothesise what the author will say before reading the document. • Evaluate the source's trustworthiness by considering genre, audience, and purpose.	• The author probably believes... • I think the audience is... • Based on the source information, I think the author might... • I do/don't trust this document because...
Contextual-isation	• When and where was the document created? • What was different then? What was the same? • How might the circumstances in which the document was created affect its content?	• Understand how context/ background information influences the content of the document. • Recognise that documents are products of particular points in time.	• Based on the background information, I understand this document differently because... • The author might have been influenced by _____ (historical context) • This document might not give me the whole picture because...
Corroboration	• What do other documents say? • Do the documents agree? If not, why? • What are other possible documents? • What documents are most reliable?	• Establish what is probable by comparing documents to each other. • Recognise disparities between accounts.	• The author agrees/ disagrees with • These documents all agree/disagree about... • Another document to consider might be...
Close Reading	• What claims does the author make? • What evidence does the author use? • What language (words, phrases, images, symbols) does the author use to persuade the document's audience? • How does the document's language indicate the author's perspective?	• Identify the author's claims about an event. • Evaluate the evidence and reasoning the author uses to support claims. • Evaluate author's word choice; understand that language is used deliberately.	• I think the author chose these words in order to... • The author is trying to convince me... • The author claims... • The evidence used to support the author's claims is...

4 How should we sequence critical thinking skills?

As with most critical thinking research, little concrete information is available about the ideal teaching sequence for various critical thinking skills. The literature about sequencing these skills is mostly based on expert-created frameworks that are often general and not domain-specific. These general frameworks can be a useful starting point for thinking about how skills progress, yet sequencing advice will be most useful to teachers if it is also domain-specific. In addition, more specific and explicit information about critical thinking sequencing has been shown to potentially be more effective for improving instruction.[120]

Because there is no one perfect or 'correct' framework for sequencing critical thinking skills, systems and educators may create different versions to test and trial in classrooms. The goal of sequencing is to get exact enough about the skill being taught so that it is clear to teachers what to focus on each term, week, and day. Sequencing critical thinking skills, unlike teaching the curriculum, does not need to be prescriptive and can be quite adaptable. However, sequencing advice that is too generic and high-level will offer little support to teachers. Hence, it can be useful to combine high-level frameworks with specific curriculum requirements.

Below, we suggest using three types of frameworks for designing critical thinking skill sequences:

- Domain-specific skills progressions (the contents of the NSW Curriculum, for example)
- General critical thinking skills frameworks (Bloom's Taxonomy or the ACARA continuum, for example)
- Pedagogical principles for sequencing (evidence-based approaches such as those in Rosenshine, 2012, for example).

Figure 10 shows three types of frameworks that can be used to develop a critical thinking skills sequence. Each of the three types is described below.

120 R Ritchhart, Intellectual Character: *What It Is, Why It Matters, and How to Get It* (1st edition), Jossey-Bass, San Francisco 2004; S Tishman & DN Perkins, 'Critical Thinking and Physical Education', Journal of Physical Education, Recreation & Dance, 1995, 66(6):24-30.

Figure 10: Framework for designing a critical thinking skills teaching sequence

Note: Pedagogical principles are based on B Rosenshine, 'Principles of Instruction: Research-based strategies that all teachers should know', American Educator, 2012.

Domain specific skills progression

History examples:

- Analysis and use of sources
- Historical investigation and research

Science examples:

- Questioning and Predicting
- Processing and Analysing Data and Information
- Problem Solving

General critical thinking skills frameworks

- ACARA Critical and Creative Thinking learning continuum
- Bloom's Taxonomy
- Solo Taxonomy

Pedagogical principles for sequencing

- Break down skills into smaller steps
- Provide scaffolds for difficult tasks
- Require lots of practice
- Review previous learning regularly

Elements of each framework can be combined to create a critical thinking skills sequence

The case study systems have frameworks in their curriculum resources that are similar to the categories below. For example, Hong Kong has curriculum resources that explicitly link to Bloom's Taxonomy. Singapore's history syllabus is organised around a Cycle of Historical Inquiry framework which sequences critical thinking beginning with guided questioning, followed by locating and analysing historical sources and using evidence to respond to the guiding questions and reflect on further questions. This is an example of a domain specific skills progression.

4.1 Domain specific skills progression

The NSW Curriculum provides teachers with information on when to teach different skills. Some syllabuses have a specified skills continuum, but all domains essentially have a progression of skills, even if this is not explicit in the syllabus. For example, the K-10 History Syllabus specifies a 'History Skills Continuum' (see Table 8). Although the Science Syllabus does not explicitly have an equivalent framework, the different stage descriptions detail the skills, so they can be pulled into a table showing the suggested progression (see Table 9).

Not all of the skills listed in the NSW Curriculum should be classified as critical thinking, which is why combining these progressions with general critical thinking frameworks is useful. Also, many skills start with lower-level process learning, which is sensible, since fluency with the process is a foundation for developing critical thinking skills. For example, "read and understand historical texts" is a basic skill that may not involve critical thinking on its own. However, it is clearly one of the most important foundational skills for all history learning, including critical thinking.

In science, a skill such as "develops questions or hypotheses to be investigated scientifically" is likely to be developed over many years, starting in lower stages with students asking questions and learning the definition of 'hypothesis'. Teachers will therefore find it useful to know which skills are important prerequisites for higher order thinking skills. Most of these prerequisite skills will need revision over time, perhaps alongside the teaching of higher order skills. For example, in science, a basic skill such as collection of qualitative data will require years of practice for a deep understanding of and fluency in the skill. Teachers can structure skill revision to link to higher order skills over time – for example, by introducing more complicated data collection tasks, or by probing students with challenging reflection questions, such as asking them to identify strengths and weaknesses in their data collection procedures.

Table 8 and Table 9 show the skills in the History and Science Syllabuses. As written, the skills are very high-level, and teachers will need to break them down into smaller steps. This approach is also supported by frameworks for pedagogy that can be used to develop more explicit sequencing, as the following sections explain. Frameworks or resources that outline how to break down and sequence broad skills across years of learning will help teachers to understand what prerequisite skills students should have. For students with skill gaps, these sequencing resources will help teachers to diagnose the next steps for their learning so that they do not fall further behind.

Table 8: NSW K-10 History Skills Continuum

	Stage 4	Stage 5
	Students:	**Students:**
Comprehension: chronology, terms and concepts	• read and understand historical texts • sequence historical events and periods • use historical terms and concepts	• read and understand historical texts • sequence historical events to demonstrate the relationship between different periods, people and places • use historical terms and concepts in appropriate contexts
Analysis and use of sources	• identify the origin and purpose of primary and secondary sources • locate, select and use information from a range of sources as evidence • draw conclusions about the usefulness of sources	• identify different types of sources • identify the origin, content, context and purpose of primary and secondary sources • process and synthesise information from a range of sources as evidence in an historical argument • evaluate the reliability and usefulness of primary and secondary sources for a specific historical inquiry
Perspectives and interpretations	• identify and describe different perspectives of participants in a particular historical context	• identify and analyse the reasons for different perspectives in a particular historical context • recognise that historians may interpret events and developments differently
Empathetic understanding	• interpret history through the actions, attitudes and motives of people in the context of the past	• interpret history through the actions, values, attitudes and motives of people in the context of the past
Research	• ask a range of questions about the past to inform an historical inquiry • identify and locate a range of relevant sources, using ICT and other methods • use a range of communication forms and technologies	• ask and evaluate different kinds of questions about the past to inform an historical inquiry • plan historical research to suit the purpose of an investigation • identify, locate, select and organise information from a variety of sources, using ICT and other methods
Explanation and communication	• develop historical texts, particularly explanations and historical arguments that use evidence from a range of sources • select and use a range of communication forms (oral, graphic, written and digital) to communicate effectively about the past	• develop historical texts, particularly explanations and historical arguments that use evidence from a range of sources • select and use a range of communication forms (oral, graphic, written and digital) to communicate effectively about the past for different audiences and for different purposes

Table 9: NSW Science Skills – Stages 4 and 5

Skill	Stage 4	Stage 5
Questioning and predicting	Identifies questions and problems that can be tested or researched and makes predictions based on scientific knowledge.	Develops questions or hypotheses to be investigated scientifically.
Planning investigations	Collaboratively and individually produces a plan to investigate questions and problems.	Produces a plan to investigate identified questions, hypotheses or problems, individually and collaboratively.
Conducting Investigations	Follows a sequence of instructions to safely undertake a range of investigation types, collaboratively and individually.	Undertakes first-hand investigations to collect valid and reliable data and information, individually and collaboratively.
Processing and Analysing Data and Information	Processes and analyses data from a first-hand investigation and secondary sources to identify trends, patterns and relationships, and draw conclusions.	Processes, analyses and evaluates data from first-hand investigations and secondary sources to develop evidence-based arguments and conclusions.
Problem Solving	Selects and uses appropriate strategies, understanding and skills to produce creative and plausible solutions to identified problems.	Applies scientific understanding and critical thinking skills to suggest possible solutions to identified problems
Communicating	Presents science ideas, findings and information to a given audience using appropriate scientific language, text types and representations.	Presents science ideas and evidence for a particular purpose and to a specific audience, using appropriate scientific language, conventions and representations.

4.2 General critical thinking skills frameworks

There are many international examples of critical thinking skills frameworks that show sample progressions for critical thinking skills. Most of these frameworks are general, not domain-specific. Two of the most relevant examples are the ACARA Critical and Creative Thinking Learning Continuum and Bloom's Taxonomy. The benefit of these frameworks is that they focus specifically on showing teachers how higher order skills develop in a continuum or sequence. By contrast, domain-specific skills frameworks often contain many skills that are not specifically critical thinking skills. Therefore, combining these two types of frameworks can help teachers understand more about sequencing the teaching of critical thinking.

Box 6:
ACARA Critical and Creative Thinking Learning Continuum

The ACARA Critical and Creative Thinking Learning Continuum underpins how the Australian Curriculum integrates content and critical and creative thinking skills. ACARA's general framework for critical and creative thinking skills includes a learning continuum covering six levels of student skill. This continuum is general, not linked to a specific domain. Because it is also very high-level it contains only overview statements, not details or descriptions of examples of what skills look like at different levels. The continuum provides a useful starting point, but teachers are likely to need more information to understand how to adapt their teaching to best sequence these skills.

Additionally, the ACARA continuum may not always be accurate in describing what skill development students at different year levels are capable of. The continuum was designed to "help teachers develop a shared understanding of the scope and sequence of the general capabilities in the Australian Curriculum" [121] but if teachers apply it directly, it may not always work. For example, the sub-element, 'Reflect on processes', states that Year 6 students should be able to 'justify the thinking behind choices they have made,' while Year 8 students should be able to 'justify the reasons behind choosing and particular problem-solving strategy'. But students are likely to be at very different points of the continuum, not just based on age but on the specific topic in which they are applying the skill. For example, there is no reason why a younger student in Year 2 would not be able to justify his thinking and choices if the learning topic was something as simple as forming patterns from a collection of stones. However, even Year 10 students would struggle to justify problem-solving strategies if the problem were very complex, and they were not familiar with their different strategy options.

In summary, the ACARA continuum can be a useful guide but is likely not enough to fully support teachers in developing plans for critical thinking skill teaching. Instead, domain-specific skill sequences might be more helpful, especially if they can be aligned with more general sequences – for example, having a science critical thinking skill sequence that is aligned with a general continuum such as ACARA's.

121 See ACARA, How are the progressions different from the general capabilities and how can they be used?.

4.3 Pedagogical principles for sequencing

Some general principles of good teaching, with a wide evidence base, are directly related to how to sequence teaching. These four evidence-based practices are highly relevant for teachers who are sequencing critical thinking skills:

1. Present new material in small steps, with student practice after each step: Teachers can present new skills (including critical thinking skills) in steps, and model with a think aloud, before student practice, for example.
2. Provide scaffolds for difficult tasks: Provide temporary supports for new and difficult tasks. Scaffolds may be tools, models, cue cards, or checklists.
3. Require and monitor independent practice: Students need extensive, successful, independent practice for skills and knowledge to become automatic.
4. Engage students in weekly and monthly review: The more students rehearse and review information, the stronger they develop their connections between learnings.

These strategies show that teachers should begin planning for teaching a new skill by breaking it down into smaller steps that students can understand and practise. Most of the skills listed in the NSW Curriculum are quite broad and teachers may benefit from support to break down the skills into sub-steps. For each skill, teachers can also sequence by scaffolding – which means first teaching the skill with support, such as a checklist, for students to follow. Then, as students practise (third in the list), and develop fluency in the skill, the scaffolds can be removed.

The use of a checklist when teaching critical thinking skills may seem counter-intuitive. But there is ample evidence that all skills, including critical thinking skills, are best taught explicitly at first, especially when the skills are quite complex. Although the goal is to have students become independent thinkers, allowing them to direct their own learning in the early phases will not help them to learn. While there is a lot of research on how experts think and learn, students are not experts. The teaching practices most likely to lead students to become experts start as teacher-directed, highly scaffolded, and explicit. In designing a sequence, these practices are useful in the beginning stages of teaching a new skill, with less guidance and more student-directed learning coming later in the sequence.

The evidence on effective pedagogies also describes the need for a continual and strategic review. Regular reviews are important to consider in sequencing the teaching of critical thinking skills so that students can develop and deepen skills over time. They also help teachers to understand when elements of skills need to be re-taught, or require more practice.

4.4 Combining the frameworks to create a skill sequence

The above frameworks could be combined to create a skills sequence in History and Science. Table 10 and Table 11 provide sample sequencing of skills for History and Science respectively.

Table 10: Sample sequencing of skills – combining general critical thinking frameworks with History syllabus objectives

Stage 1-3	Stage 4	Stage 5	Stage 6
Skill Continuum from NSW Curriculum – Skill: Analysis and use of sources			
Understand what a source is, how to retrieve information from it, and how to **compare information from multiple sources**.	Understand primary vs secondary sources, how to use them to answer inquiry questions, and how to **analyse the usefulness of different sources**.	Classify source types, **synthesise source information to make arguments, evaluate the limitations of sources**.	Use sources to **analyse perspectives, develop arguments and evaluate limitations of sources**.
• Explore and use sources • Locate information relevant to inquiry questions in sources • Compare information from sources	• Identify the origin and purpose of primary and secondary sources • Locate, select and use information from sources as evidence • Draw conclusions about the usefulness of sources	• Identify different types of sources • Identify the origin, content, context and purpose of primary and secondary sources • Process & synthesise information from sources as evidence in an historical argument • Evaluate the reliability and usefulness of primary/secondary sources for a specific historical inquiry	• Explain the meaning and value of sources • Analyse sources to identify and account for the different perspectives of individuals and groups in the past • Analyse & synthesise evidence from different types of sources to develop reasoned claims • Identify & analyse problems relating to sources
Sample hierarchical learning goals from Bloom's Taxonomy			
• **[Define]** What is a source? • **[Compare]** What information is similar or different between three sources? • **[Evaluate]** Which source is most/least useful to answer X question?	• **[Define]** What are primary vs secondary sources? • **[Classify]** Practise classifying primary vs secondary sources. • **[Compare]** What different information is gained from primary vs secondary sources? • **[Evaluate]** Are primary sources 'better' than secondary sources? • **[Create]** Make your own checklist to step through an evaluation of a source's usefulness.	• **[Define]** What are the different types of sources? • **[Apply]** Practise pulling information from sources on the origin and context of the source. • **[Infer]** What does this information tell you about the source? • **[Analyse]** What does the information tell you about the inquiry question? • **[Evaluate]** What is the reliability and usefulness of the source? • **[Critique]** Other students' work – what are they identifying or missing about source limitations? What does their analysis show you about strengths / limitations of your own?	• **[Define]** How would you define a 'perspective'? (e.g. perspective of an individual in the past). • **[Apply]** Practise using sources to identify perspectives. • **[Analyse]** Use multiple sources to synthesise information on perspectives. • **[Critique]** How useful and reliable are the sources for this analysis? • **[Critique]** What are the problems with the sources? • **[Produce]** Report for a historical journal on your conclusions, identifying limitations and what this means for future historians.

Stage 1-3	Stage 4	Stage 5	Stage 6
Sample questions based on the ACARA Critical and Creative Thinking Continuum			
• **[Pose questions]** After reviewing this source, what is one new question you have about it? • **[Identify and clarify information and ideas]** Identify and explore information and ideas from source materials. • **[Reflect on processes]** What process did you use to locate information in sources (e.g. skimming, fully reading, etc.)? Is your process different than other students in your class?	• **[Pose questions]** What are the three key questions you would want to ask about this source before using it as evidence? • **[Identify and clarify information and ideas]** How would you *prioritise* the pieces of information provided by this source? What is the most useful piece of information, second most useful ... and why?	• **[Apply logic and reasoning]** Review a historian's analysis and her sources – what are the gaps in her reasoning? Why did she choose these sources and what are their limitations? • **[Metacognition]** Can you identify assumptions you made about the sources that were not explicit in the text? Where did these assumptions come from? How did your assumptions affect your analysis?	• **[Apply logic and reasoning]** Peer review others' analysis – what are some gaps in their conclusions? What do others' analysis show you about gaps in your own reasoning? • **[Metacognition]** Reflect on your process for source analysis – what weaknesses might you have, compared to other students or professional historians? What skills/ knowledge would help you produce higher quality analysis?

Table 11: Sample sequencing of skills – combining general critical thinking frameworks with Science syllabus objectives

Stage 2	Stage 3	Stage 4	Stage 5
Skill Continuum from NSW Curriculum – Skill: Questioning and predicting			
• identify and pose questions in familiar contexts that can be investigated scientifically • make predictions based on prior knowledge	• pose testable questions • make and justify predictions about scientific investigations	• identifies questions and problems that can be tested or researched and makes predictions based on scientific knowledge	• develops questions or hypotheses to be investigated scientifically
Sample hierarchical learning goals from Bloom's Taxonomy			
• **[Define]** What is a prediction? • **[Explain]** How do scientists use data to answer questions and make predictions? • **[Apply]** Practise making predictions based on your prior knowledge. • **[Evaluate]** Was your prediction accurate?	• **[Define]** What is a testable question? • **[Classify]** Practise classifying testable and non-testable questions. • **[Infer]** Does the data answer your question? • **[Analyse]** Practise analysing primary and secondary data to make predictions. • **[Generate]** Predict and justify what might happen in a scientific investigation.	• **[Define]** How do scientists test questions and make predictions? • **[Identify]** Questions and problems that can be tested or researched. • **[Apply]** Practise using primary and secondary data to justify your predictions and make conclusions. • **[Produce]** A report that presents and analyses data and draws conclusions about the questions you posed. • **[Critique]** What are the limitations of your scientific investigation?	• **[Define]** How do scientists use data to reject or support a hypotheses? • **[Apply]** Develop your own hypotheses to test • **[Analyse]** Practise analysing primary and secondary data to reject or support your hypotheses. • **[Produce]** A report that presents and analyses data, draws conclusions about your hypotheses, and identifies limitations of your scientific investigation. • **[Critique]** How could your investigation be improved?
Sample questions based on the ACARA Critical and Creative Thinking Continuum			
• **[Transfer knowledge into new contexts]** What are the links between this topic and the ones we have studied previously? How can we use our prior knowledge to better understand this topic? • **[Evaluate procedures and outcomes]** Was your prediction accurate? Explain why/why not? • **[Reflect on processes]** What process did you use to *make* your prediction? How would you do it differently next time?	• **[Apply logic and reasoning]** Is there enough evidence to justify your prediction? • **[Reflect on processes]** What process did you use to *justify* your prediction? How would you do it differently next time?	• **[Apply logic and reasoning]** How reliable and useful is the data? Are there any gaps? • **[Evaluate procedures and outcomes]** Were there any unexpected results? If so, what might have caused these? • **[Metacognition]** Can you identify assumptions you made about the data? Where did these assumptions come from? How did your assumptions affect your analysis?	• **[Apply logic and reasoning]** Peer review others' analysis of the data – what are some gaps in their conclusions? What do others' analysis show you about gaps in your own reasoning? • **[Draw conclusions and design course of action]** Does the data support or reject your hypotheses? What were the limitations of your investigation? How could you improve your investigation next time?

5 What knowledge do teachers need to teach critical thinking?

There is a growing consensus that two types of subject expertise are necessary to teach well:[122]

- **Content knowledge**: a deep foundation of factual knowledge about the subject being taught
- **Pedagogical content knowledge**: understanding of how to best teach the subject

All teachers need a specific body of knowledge known as subject expertise. Subject expertise is not the same as the knowledge held by the average adult. Most adults have content knowledge in the subject(s) they are most expert in (such as biology content knowledge if they are a biologist), but they do not know how to teach the subject. Pedagogical content knowledge is important because it is the knowledge (building on content knowledge) that is specific to teaching in a given domain.

Today new ideas are emerging about the specific types of knowledge teachers may need in order to teach critical thinking. These theories build on the idea of pedagogical content knowledge and specify that teachers are likely to need a separate, but closely linked, body of knowledge about how to teach critical thinking in particular domains.

For example, there are four potential categories of knowledge for teaching critical thinking:[123]

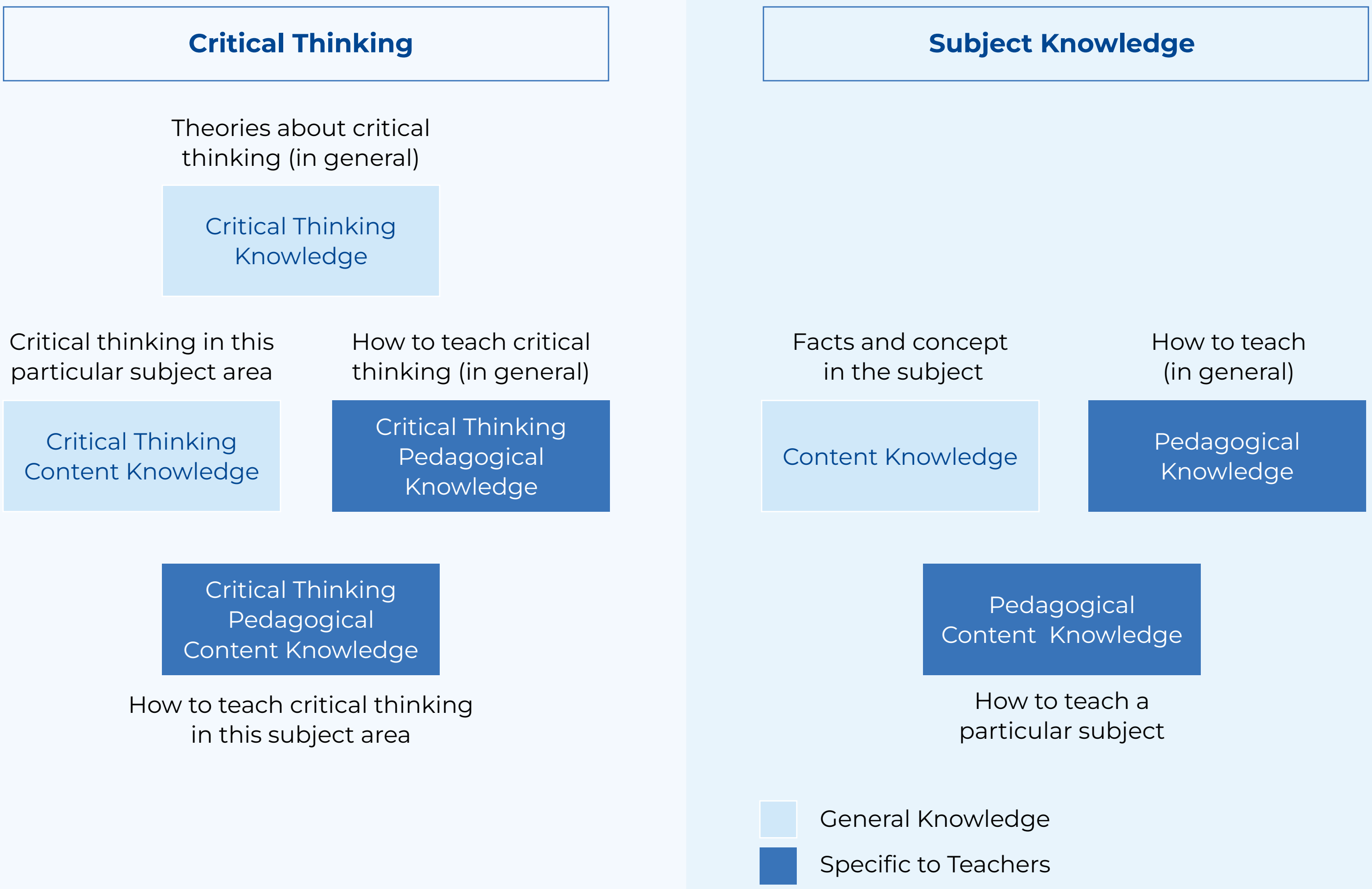
1. **Critical thinking knowledge**: General knowledge about what critical thinking is and looks like
2. **Critical thinking content knowledge**: What is unique about critical thinking within a specific domain (e.g. critical thinking in science)
3. **Critical thinking pedagogical knowledge**: Knowledge of how to teach critical thinking
4. **Critical thinking pedagogical content knowledge**: Knowledge of how to teach critical thinking in a specific domain (such as in science class).

These four types of knowledge interact with subject knowledge, as shown in Figure 11. More details about each type of knowledge are outlined below.

122 National Research Council, *Preparing teachers: Building evidence for sound policy*, The National Academic Press, Washington DC, 2010; M Allen, '[Eight Questions on Teacher Preparation: What Does the Research Say? A Summary of the Findings]', Education Commission of the United States, 2003; R Coe, C Aloisi, S Higgins, & LE Major, '[What makes great teaching? Review of the underpinning research]', Sutton Trust, 2014

123 M Ab Kadir, 'What Teacher Knowledge Matters in Effectively Developing Critical Thinkers in the 21 st Century Curriculum?', *Thinking Skills and Creativity*, 2017, 23:79-90.

Figure 11: Types of knowledge teachers need



Content knowledge

A range of reports and studies published from the 1980s[124] onwards show what may seem obvious: that the most effective teachers generally know a lot about the subjects they are teaching.[125] They have a "profound understanding" of the concepts taught in school; in other words, they understand the content they are teaching in-depth, accurately, and without confusion.[126]

The content knowledge most useful to teachers may differ from what professionals in the field need to know.[127] For instance, primary teachers may not need to know much about advanced science concepts such as spectroscopy, but they should be experts in the concepts taught to young students, such as states of matter.

The concept of a profound understanding has been extensively investigated in mathematics and, to a lesser extent, science and literacy and other

124 National Research Council, *Preparing teachers*; L Darling-Hammond & J Bransford, *Preparing teachers for a changing world – what teachers should learn and be able to do*, Jossey-Bass, Indianapolis, 2005; Coe et al., 'What makes great teaching?'; Allen, 'Eight Questions on Teacher Preparation'.

125 PF Campbell, M Nishio, TM Smith, L Clark, DL Conant, AH Rust & Y Choi, 'The Relationship Between Teachers' Mathematical Content and Pedagogical Knowledge, Teachers' Perceptions, and Student Achievement', *Journal for Research in Mathematics Education*, 2014, 45(4):419-459; DN Harris & TR Sass, ' Teacher training, teacher quality and student achievement', *Journal of Public Economics*, 2011, 95(7):798-812; J Metzler & L Woessmann, 'The impact of teacher subject knowledge on student achievement: Evidence from within-teacher within-student variation', *Journal of Development Economics*, 2012, 99(2):486-496; National Research Council, *Preparing teachers*.

126 L Ma, *Knowing and teaching elementary mathematics*, Routledge, New York, 1999.

127 RE Floden & M Meniketti, ' Research on the effects of coursework in the arts and sciences and in the foundations of education' in M. Cochran-Smith & K. M. Zeichner (eds.) *Studying teacher education: The report of the AERA panel on research and teacher education*, 2005; Harris & Sass, 'Teacher training'.

domains.[128] Nevertheless, many efforts to build teacher knowledge have focused on advanced concepts education rather than a profound understanding of the fundamental content taught in primary or secondary school.[129]

Yet simply requiring teachers to take more subject courses or hold advanced degrees will not necessarily lead to stronger content knowledge relevant to primary and secondary teaching.[130] Required courses that focus on content taught in schools – aligned to the curriculum – are likely to produce better outcomes.[131]

Pedagogical content knowledge

Pedagogical content knowledge is knowledge of how to teach the content of a specific subject. As with content knowledge, greater teacher pedagogical content knowledge is correlated with greater student learning.[132]

Pedagogical content knowledge differs from content knowledge in that it involves an understanding of how students learn, how to translate a conceptual understanding into compelling examples for students, how to identify and correct student misconceptions, and how to explain how new concepts relate to previous learning.

Pedagogical content knowledge is also specific to a given subject.[133] To teach reading, teachers should deeply understand the process of learning to read and have an array of strategies to help young readers. In maths, pedagogical content knowledge includes an understanding of how maths knowledge develops in students and the ability to anticipate student thinking as students approach maths problems. Science teachers need to understand which instructional approaches are best for the different types of science content they are teaching.

Figure 12: Different types of subject expertise

Pedagogical content knowledge differs from content knowledge in that it requires the interaction of content with the knowledge of students and the knowledge of teaching. Teachers must be able to:

- Anticipate student thinking
- Choose the best representations
- Analyse the challenge or ease of tasks

	Content knowledge	Pedagogical content knowledge
Maths	Understanding that 1 ⅔ is the same as 5⁄3 and how to prove that that is true.	Anticipating that students might confuse the numerator and the denominator when converting fractions.
Science	Understanding the fundamental concepts of natural selection (genetic variation, heritability).	Knowing which examples best illustrate of genetic diversity and anticipating questions students may have.
Reading	Knowing what phonemes are (units of sound that make up words).	Knowing ways to improve student phonemic awareness for literacy (the ability to notice how sounds in words work).

128 DL Ball, HC Hill, & H Bass, 'Knowing Mathematics for Teaching: Who Knows Mathematics Well Enough To Teach Third Grade, and How Can We Decide?', *American Educator*, 2005, 29(1):14-46.

129 DL Ball, MH Thames, G Phelps, ' Content Knowledge for Teaching: what makes it special?', *Journal of Teacher Education*, 2008, 59(5):389-407.

130 J Kilpatrick, J Swafford, & B Findell, *Adding it up: helping children learn mathematics*, National Academies Press, 2001; Allen, 'Eight Questions on Teacher Preparation'.

131 RA Duschl, HA Schweingruber, & AW Shouse, *Taking Science to School: Learning and Teaching Science in Grades K-8*, National Academies Press, Washington DC, 2007.

132 M Evens, J Elen, & F Depaepe, 'Developing Pedagogical Content Knowledge: Lessons Learned from Intervention Studies', *Education Research International, Education Research International*, 2015.

133 National Research Council, *Preparing Teachers,* 2.

Critical thinking knowledge

While content knowledge and pedagogical content knowledge have been well-researched for decades, all types of knowledge specific to critical thinking are relatively new theories.[134] For example, critical thinking knowledge is knowledge of theories and ideas about critical thinking. Teachers might benefit from this knowledge in understanding the different definitions of critical thinking and what is known and not known about how critical thinking might be transferred between different domains.

Critical thinking content knowledge

Critical thinking content knowledge includes the knowledge of critical thinking in a particular domain. For example, what critical thinking looks like in science as opposed to history. This knowledge may be held by people who are not teachers, but teachers may require a specific subset of critical thinking content knowledge.

Critical thinking pedagogical knowledge

Critical thinking pedagogical knowledge refers to the knowledge of the various pedagogies, strategies and approaches available for teaching critical thinking in general.[135] This might include knowledge of:

- a variety of thinking skills or strategies, including metacognitive skills
- pedagogies that would engage students in tasks that require thinking skills
- how to engage students in the “language of thinking”, in metacognitive thinking, in the transfer of thinking skills across various subjects, and in cultivating thinking dispositions.[136]

This category also includes knowledge of how to employ types of thinking routines or approaches. Critical thinking pedagogical knowledge is about ‘how’ to get students to be critical thinkers. It is knowledge of the pedagogical applications of various critical thinking strategies, which makes it similar to the notion of pedagogical knowledge.

Critical thinking pedagogical content knowledge

Critical thinking pedagogical content knowledge includes the ‘what’, ‘how’, and ‘why’ knowledge of critical thinking that is essential for teaching critical thinking effectively in a particular domain.[137] The more a teacher knows the various forms of understanding of critical thinking, the more able she is to find the most appropriate approach when teaching.

Many experienced teachers have pedagogical content knowledge that helps them to teach their subjects, but emerging research suggests that teaching critical thinking requires knowledge specific to critical thinking. For example, one study found that teachers’ conceptions of thinking influence how they approach teaching higher order, or critical thinking skills, in their classrooms.[138] Similarly, another study found that teachers’ teaching of critical thinking is dependent on their knowledge base of how to teach it (that is, critical thinking pedagogical knowledge and critical thinking content knowledge).[139]

This knowledge differs from subject knowledge and would not typically be held by non-teaching subject-matter experts or even generalist critical thinking experts.

134 Ab Kadir, ‘What Teacher Knowledge Matters’.

135 Ab Kadir, ‘What Teacher Knowledge Matters’.

136 A Zohar & N Schwartzer, ‘Assessing Teachers’ Pedagogical Knowledge in the Context of Teaching Higher-order Thinking’, *International Journal of Science Education*, 2005, 27:1595-1620.

137 Ab Kadir, ‘What Teacher Knowledge Matters’.

138 Ritchhart, *Intellectual Character*.

139 Zohar & Schwartzer, ‘Assessing Teachers’ Pedagogical Knowledge’.

We acknowledge the homelands of all Aboriginal people and pay our respect to Country.

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