Author/s:
Stevenson, E;Dawborn-Gundlach, M;van Driel, J

Title:
Practices for Developing Students' Science Inquiry Skills: Insights from Secondary School Teachers

Date:
2024-09

Citation:
Stevenson, E., Dawborn-Gundlach, M. & van Driel, J. (2024). Practices for Developing Students' Science Inquiry Skills: Insights from Secondary School Teachers. Teaching Science, 70 (3), pp.8-21

Persistent Link:
https://hdl.handle.net/11343/354348

Practices for Developing Students' Science Inquiry Skills:

Insights from Secondary School Teachers.

Emma Stevenson, Merryn Dawborn-Gundlach, Jan van Driel
Faculty of Education, The University of Melbourne

Abstract

Being scientifically literate is an essential twenty-first century skill for every individual navigating today's complex world and science inquiry skills are seen as an important capability of a scientific literate person. However, teaching science inquiry skills requires specific competences and is often challenging for teachers. Understanding the practice and challenges of experienced teachers is essential for designing bespoke support (e.g., professional learning programs, or coaching and mentoring). This study was guided by the following question: What practices do Victorian science teachers use to develop their students' science inquiry skills? To answer this question, we interviewed six experienced Victorian science teachers focusing on how they aim to develop science inquiry skills among their Year 7 and 8 students. The study found pedagogical suggestions for developing students' science inquiry skills which may serve to inspire professional learning and curriculum development for other science teachers.

Introduction

Being scientifically literate is an essential twenty-first century skill for every individual navigating today's complex world. Science inquiry skills are seen as an important capability of a scientific literate person and are addressed in many curriculum documents internationally (Australia: ACARA, 2018; USA: NGSS Lead States, 2013). However, teaching science inquiry skills requires specific competences and facilities and is often challenging for teachers. One of these challenges concerns planning and delivering open-ended, hands-on activities that enable students to engage in authentic experimentation. This approach often requires considerable time and resources to implement effectively within the constraints of crowded curricula and limited classroom and laboratory hours (Akuma & Gaigher, 2021). Furthermore, fostering a genuine understanding of scientific inquiry necessitates facilitating an environment where students feel safe to ask questions, make mistakes, and engage in open-ended exploration, requiring a departure from traditional teacher-centred models of instruction (Oliveira, 2010).

With these challenges in mind, we conducted a study among science teachers to explore their current practice and their views and ideas that underpin this practice. Understanding the perceptions and experiences of teachers is essential for designing bespoke support (e.g., professional learning programs, or coaching and mentoring). The study was guided by the following question: What practices do Victorian science teachers use to develop their students' science inquiry skills? To answer this question, we interviewed six Victorian science teachers focusing on how to develop science inquiry skills among their Year 7 and 8 students. The study found pedagogical suggestions for developing students' science inquiry skills which may serve to inspire professional learning and curriculum development for other science teachers.

Literature review

The Organisation for Economic Cooperation and Development (OECD) defined scientific literacy to frame their Program for International Assessment (PISA) as "a students' ability to understand, use and reflect on written texts in order to achieve one's goals and to participate in society" (OECD, 2006). To be scientifically literate means understanding basic scientific knowledge, and having skills related to the process of science inquiry, such as questioning, predicting, designing, and conducting experiments (Osborne, 2013). Science inquiry offers a natural pathway for developing scientific literacy since it empowers learners to question, investigate, and analyse the natural phenomena around them, enabling them to make informed decisions, critically evaluate information, and contribute meaningfully to society (Osborne, 2013; Osborne et al., 2023). Given the spread of scientific misinformation, students should be able to understand how scientific knowledge is developed, reviewed, revised, and eventually accepted by the scientific community. In other words, students need to learn the process of scientific inquiry.

To prepare students for a world in which scientific understanding and skills are needed to make informed decisions, the Australian F-10 curriculum aims to help students understand central scientific concepts and scientific processes and the role of science in society (ACARA, 2022). Science inquiry skills are one of the three interrelated strands for the learning area of science, together with science understanding, and science as a human endeavour. The science inquiry strand specifies scientific inquiry skills in terms of questioning and predicting; planning and conducting; processing and analysing data and information; evaluating; and communicating (ACARA, 2022). As a cross-disciplinary thread, teachers must connect the teaching of science inquiry skills with specific content (from the science understanding strand) and with the nature of science as a human endeavour (ACARA, 2022).

Method

Study Purpose, Participants, and their Recruitment

This qualitative study aimed to investigate the knowledge and practice of science teachers in Victoria in teaching their Year 7 and 8 students about scientific inquiry and reasoning. For this purpose, Victorian science teachers were invited to contribute to the research. After receiving approval from the University of Melbourne Human Research Ethics Committee (2023, Ethics ID Number: 26967), an invitation to participate in the study was made available to practising science teachers throughout Victoria.

The researchers contacted their existing networks of practising teachers in schools, both informally (through their own teaching colleagues, known schools and former graduates) and formally through networks such as the Science Teachers' Association of Victoria (STAV), and invited them to participate.

Teachers who registered their interest were then contacted by email to agree on a mutually conducive time for the interview. Six teachers, all working in schools in metropolitan Melbourne, agreed to be interviewed. Table 1 presents further demographic information for each participant.

Participant pseudonym	Years of teaching experience	Experience with science inquiry skills in previous work or study prior to teaching
Caroline	>14	yes
Greg	>14	yes
Kim	5-14	yes
Paul	5-14	yes
Brad	5-14	no
Cathy	5-14	no

Table 1. Demographic information for interview participants

Consent Forms and Plain Language Statements, explaining the purpose and methodology of the study, steps to maintain confidentiality and the voluntary nature of participation in the study were provided to participants. The six interview participants were given a pseudonym.

Data Collection and Analysis

Data was collected through semi-structured interviews and consisted of five open questions (e.g., from the content areas of biology, chemistry, physics, space and earth science, which are useful for developing science inquiry skills in science lessons?). Here, teachers discussed and reflected on the practices they use in their year 7 and 8 science classrooms. While varied prompts relating to teaching practices and science inquiry skills were utilised by the interviewer, using the same questions ensured that each interview followed a similar pattern, with some flexibility for the interviewee to reflect and elaborate on specific questions. The interview questions, found in appendix A, ensured responses related to answering the project's research questions. Each interview was conducted online and recorded using Zoom and transcribed by the first author.

The average interview time was 30 minutes. A small compensation in the form of a gift voucher was offered to participating teachers in the interview to partially compensate for the time spent being interviewed and their contribution to the study.

The interview data was initially analysed by grouping responses related to each question. For example, participants were asked how they support student learning of writing methods, so relevant responses were grouped and compared. Further analysis involved determining emerging themes from the data set and re-reading each interview to ensure consistency across each teacher. Four themes, relating to different teaching practices, were identified and will be used to present our findings in the next section.

Findings & Discussion

Responding to the question guiding this research- what practices do teachers use to develop students' science inquiry skills? - this section illustrates and discusses the four themes arising from teacher interviews.

Practice 1: Relating learning and skill development to everyday contexts

Throughout the interviews, participants spoke of their classes exploring topics or scenarios that relate to everyday life. While introducing these skills, teachers also considered the motivation, interest, and engagement of their students. For example, one teacher spoke of using a local issue for encouraging students to think about an inquiry.

We've got a little wetland at the bottom of this school ...one of the jobs of a wetland is to clean the water. But is the water clean enough for us to drink? Let me get a sample, and we go 'oh, there's really bits in it. No, it's not clean enough.' What does clean water look like? How do we know it's clean? You can imagine how we can purify it.... With the wetlands. It's more of a call to action to 'let's save our wetlands.' Our wetlands are under threat, this is our solution, and how we propose to keep litter out of them. (Paul)

In this situation, Paul utilises a real issue in a local wetland to encourage students to explore an inquiry based on the context. While there does not appear to be a specific science inquiry skill being developed in this scenario, the aim is motivational with Paul posing a 'call to action,' and guiding student thinking about inquiry and its design through questioning. As another example of using real-life contexts, Caroline spoke of a local issue for encouraging students to plan an inquiry:

Anytime you do anything in the kitchen, it [the recipe] tells you all the things that you need, and then it goes through steps 1-7 in detail. Your method needs to be like that. Your method needs to be something that one of your peers could pick up and do it as you wanted it to be done...... so it's always in relation to their data, to their own experience, to what they've just done.

Here Caroline is developing students' understanding of method design by relating it to an everyday activity that students are likely to be familiar with such as the instructions for cooking a cake. Highlighting the stepwise nature of recipes provides an analogy for students to connect with their learning of method design. This example illustrates the development of the skills related to method design, both explicating the steps and communicating, so that others can replicate. Additionally, teacher questioning is valuable for students' understanding the 'elements that we should be considering' (Brad) when writing a method, however, it is 'the process of them trying' (Paul) which helps students to recognise the challenges of this skill development. For the teachers in this study, it seems important for students to 'separate it from the science content' (Cathy) when learning about designing a method. Relating to real life activities means that students are already familiar with and can visualise the steps involved.

Everyday contexts were also used to develop student understanding of different variables.

> *Critically analysing some science in popular culture to be like how do we know that's true? What were the confounding variables? Once I get to year 9, we do a lot of naming variables. So, whether they're dependent, independent, confounding, controlled and giving them names and knowing that things can get in the way, and having a word for that, I think, is powerful for them. So, we'll often talk about conclusions and the way they're presented in the media. How would the science behind them have been? And* is that a valid thing to say? (Kim)

By posing, discussing, and questioning examples sourced from the media, students analyse the validity of the media reports about these everyday topics, developing understanding of variables. Teachers value the use of real-life topics when developing students' inquiry skills, as strongly evidenced by the data presented here. Teaching through real life contexts is not novel to developing science inquiry skills and research demonstrates that increased student interest arises when learning through context-based teaching (Bennett et al, 2007; King, 2012). Of note, in this study, is the variation in the types of real-life topics utilised, as well as the use of contexts which are familiar and relevant to students. Cognitive Load Theory suggests that to promote learning, educators need to minimise the amount of information imposed on students' memory (Kirschner, 2002). When learning a new skill (e.g., how to write a method), using a familiar real-life topic minimises cognitive load since students are only remembering the new skill. Given that the topics illustrated in this study were primarily teacher directed, it is important to carefully consider the examples used when teaching science inquiry skills to ensure that students can relate to the real-world topics explored in their learning (Chen & Cowie, 2013). These findings indicate that real-life topics hook students into inquiry investigations and develop their understanding of variables and method design, serving both cognitive and affective learning outcomes.

Practice 2: Modelling Science Inquiry

Teachers spoke of using modelling to support students learning science inquiry skills and modelling these skills. This section explores the nature of the modelling, how they were used by teachers and discusses why this teaching practice is valuable.

As an example of modelling, teachers in this study often discussed how they would demonstrate inquiry skills to students.

> *I would demonstrate a small demo within chemistry and demonstrate that this is one [a variable] that's going to change. This is what I'd like to measure, and I'm now going to think through all the things I'm going to have to keep the same. So, I would explicitly model that to students.* (Cathy)

> *I have the best sock demo - cotton vs. wool vs. synthetic. I had a method stepped out, putting different socks on different cans of cola, aluminium cans- putting hot water in, with a thermometer and watching the temperature fall as the sock was better or worse insulated. And I've written it all up for them, here's how the method works, and this is the recipe for getting the data I need from this experiment. So, I do it as a demonstration.* (Greg)

These quotes indicate that teachers value demonstrations for explicitly illustrating to students' what science inquiry skills look like in practice. While the focus here is on different skills (e.g., variables, method design), the teacher-led demonstration provided observable modelling to support students' understanding of each skill.

Teachers also spoke about providing templates for students to work with and use as exemplars, particularly in their initial learning of a science inquiry skill.

> *And then we prompt them of how to write the aim. The aim is written in the form of 'to investigate the effect of the IV on DV'.... So, when they get to the conclusion they're expected to say 'my research question was, blah blah blah. My hypothesis was right. The results did or did not support the hypothesis. They do get their hands held right through that last section. So, by the end of the term, they've got an entire picture and a final lab report. And then we say, every lab report you do is going to be based on this framework, right?* (Caroline)

As Caroline discussed, these completed templates are then a reference for students in the future when they are working independently and need a reminder of their learning. The gradual withdrawal of the amount of teacher support, changing from teacher-led modelling to more student independence (e.g., peer review) over time was also highlighted. Like Caroline, Brad discussed the importance of providing scaffolding, but instead used checklists and examples when students are practising a new skill, giving *'them confidence that they can master or perform that particular skill'* (Brad).

Teachers discussed providing students with opportunities to analyse examples of practical reports, which model elements such as scientific writing and how to record and present scientific findings. For some, the examples provided contain errors, and students need to apply their understanding of the skill to fix the mistakes:

> *I'll give them some work that they'll have to correct, and they'll have to put in the real science words. So, the work might have missing things, or the table's not right or there won't be units, and the words will be wrong, and they'll have to actually fix it.* (Kim)

Analysing the examples to correct any mistakes provides students with opportunities to practise their understanding of a science inquiry skill. The teachers in this study also discussed this analysis process with respect to student examples to *'showcase some of their elements where students have done things really well'* (Cathy). The peer analysis process involves students analysing and explaining the strengths and weaknesses of a skill.

For example,

> *In year 8 I get them to start peer reviewing each other's work. ...Write out your conclusion, and then review someone else's conclusion, I just give them a little bit of 'I want you to look for these points.' And then they'll start to see them, and they start to get really good.* (Kim)

Despite being time consuming, the peer review process offers students the opportunity to analyse, evaluate and provide feedback on a model of a science inquiry skill in question. As Kim mentioned, exploring these peer models helps students get 'to know what looks good and bad,' developing their understanding of the skill.

Modelling is common practice in science education for explaining ideas to students (Duit, 1991), and the findings presented in this section illustrate that teachers find modelling valuable for helping students to visualise science inquiry skills. With a particular focus on demonstrating the skills of identifying variables, writing a method, and recording and presenting findings, teachers use modelling to provide visual representations of science inquiry skills. Of note, in this study, is the variation in the types of modelling that are useful, with approaches ranging from teacher-led demonstrations through to student peer review. Recommended for successful modelling is the provision of multiple opportunities for students to learn how to visualise phenomena (Prain & Tytler, 2012) and 'individual and group activity by students, the teacher to adopt the role of tutor' (Gilbert & Justi, 2016, p137). Also suggested throughout the findings is that teacher-led modelling is used early in the learning journey (e.g., early in year 7), with teachers moving into a facilitation role in student-led modelling as students develop confidence in their skills. This learning progression is discussed further in Practice 4.

Practice 3: Explicitly Teaching Mathematical Skills

All teachers interviewed in this study discussed developing their students' mathematical skills. Graphing was a key focus for teachers, with Greg noting that 'you must unpack graphs,' and emphasise what a graph is or does, the different types of graphs, and how to choose the best graph to represent collected data. This aligned with the approaches of other teachers. For example, Brad emphasised an explicit approach to helping students recognise the important elements of a graph:

> *So, we're explicit in the expectations on the basic format that that graph should have. And then we have a checklist approach moving forward in order for them to be practising. And so, we really need to break it down into very small components in terms of- it's pretty explicitly taught. And then it's just modelled afterwards.* (Brad)

Here, Brad provides checklists and acronyms for students to refer to when practising their mathematical skills during an inquiry. Kim discussed how to support students' understanding of which graph to use for distinct types of data:

> *So, Excel is good at showing you the types of data vis [visualisation] that are relevant to the type of data you have. We talk about why some things are greyed out [in Excel]. And you're going to need to do a histogram before you can use that. Why do you think that is? And so, I'm starting to [get students to] understand the differences in our data that drives the different visualizations. And then sometimes, when there's more than one type that's relevant, we'll do them all and say which one makes the most sense?* (Kim)

Creating and comparing graphs in Excel helps students to understand why different graphs are used for certain data sets. Of importance is teacher questioning to support their comparison, discussion, and justification for graphical use in their inquiries. Further to this, Cathy discussed the support needed for students when they are creating their graphs. For Cathy, using straightforward numbers, that are simple to manipulate was important when students are creating graphs:

> *Trying to lower the numeracy demands, so that students could do the calculations or the graphing or the overall results processing and presenting skill to the best of their abilities of doing without necessarily relying on the numbers... So, I might purposely manipulate the numeracy, the mental math, or the calculation requirements so that they can have a go at the underlying skills that I'm looking for. I'm also working with their math teacher. And we've got a joint curriculum that we're planning in there, being assisted across both subject areas.* (Cathy)

In this example students are learning a new skill- graphing- and so using simple numbers helps to reduce their cognitive load, the value of which was discussed in Practice 1. Additionally, Cathy speaks of co-creating a 'joint curriculum' with a mathematics teacher, likely to reinforce the teaching and learning of the relevant mathematics skills across multiple subjects. This teacher collaboration may also support Cathy in developing pedagogical knowledge for mathematics teaching which is suggested as an approach for developing content-area expertise (Morrison & McDuffie, 2009) and ensuring that students are not presented with conflicting language and mathematical techniques (Orton and Roper, 2000). However, such collaborations may not be straightforward. Wong and Dillon (2019) identify an asymmetry of dependency, meaning that there are more benefits for science teachers than mathematics teachers when working together.

All teachers in this study emphasised the importance of teaching mathematical skills when learning about inquiry. To integrate mathematics and science education, 'teachers require knowledge of the 'other' subject' (Riordain, et al, 2016 p. 247), in the case of science teachers, mathematics content and pedagogical knowledge. Collectively this data illustrates that knowledge of diverse types of graphs, when to use them, and how to create them is considered valuable for students. Explicit teaching strategies (e.g., checklists, acronyms), graphical comparisons and students practising them were considered valuable for developing these skills. Effective mathematics education consists of a range of pedagogical approaches including identifying and building on students' mathematical language and connecting mathematics learning with real life examples (Anthony & Walshaw, 2009). However explicit teaching is only one of many practices that teachers could use to achieve effective mathematics learning. So, one might question why this teaching strategy dominated this study for this skill development when a range of practices were employed to develop other science inquiry skills. Is it because teachers are crossing over to another domain (i.e., teaching out-of-field) or lack of time in the curriculum for more student-centred approaches to teaching? This study demonstrates that teachers are aware of progressive learning and removing scaffolds as students become more confident, however this removal of scaffolding was not as evident when teaching mathematics skills.

Practice 4: Supporting Skill Development across Different Year Levels

Teachers often talked about the different knowledge and approaches used with different year levels when teaching science inquiry skills, suggesting that there is a learning progression. Several teachers spoke of what they would teach in year 7:

> *So, in term one, we really focus on only the variables, collecting the data and then graphing it......But so our real focus, the absolute core essential of term one is all our variables so independent, dependent, and controlled. Getting the data, that's the easy part, graphing... so, it's very, very much scaffolded.* (Caroline)

> *I think that in year 7 the sequence would be method, results, discussion.* (Paul)

These quotes illustrate that teachers considered learning as a progression when developing students' science inquiry skills. This was further confirmed when they discussed what they would teach at higher year levels.

> *So, at higher levels, I might be going more into detail about controlling variables and then looking at confounding variables.* (Cathy)

> *We don't do conclusions and action till much later. That's one of the last things that we do for year 7. Because at year 7 to 10, we have a full matrix of skills that we introduce... And so, we try to build a strong sense of data... the sense of data before we get to conclusions. Towards the end of 8 we'll really start to talk about errors and stuff like that. We introduce only random at year 8, and then by year 9, they're expected to do random and systematic errors.* (Brad)

These teachers highlight that the learning progression for each skill moves deeper from one year level to the next, achieved by '*break[ing] down all the skills into individual components and then reconstruct[ing] them'* (Brad). Several teachers spoke of the teaching practices that varied from one year level to the next, when supporting student development of science inquiry skills. Caroline noted that 'different practices [are] needed' however, Kim elaborated further on how the practices changed as the year levels progressed:

> *For a year 7, I would give them a partially completed something and get them to work as a pair to complete it. So, I'm leaving small choices for them to make. And as they go through the years those choices get bigger and bigger.* (Kim)

This quote highlights that when developing students' science inquiry skills, particularly in younger year levels, the support required is to build their confidence.

These findings illustrate that utilising a learning progression when teaching science inquiry skills, means teaching some (simpler) skills in younger year levels, with considerable teacher support, and then introducing more challenging skills in later years. For some teachers, this learning progression also involves identifying and teaching each of the sub-skills that make up the science inquiry skills. While using a learning progression is common practice in everyday teaching, interestingly the sub-skills for science inquiry skills are absent from local curricula. For example, the Victorian Curriculum (VCAA, 2015) illustrates that when moving from year 7 through to year 10, students will progress from identifying to formulating questions that can be investigated scientifically yet offers limited guidance on the sub-skills required by students to develop their capacity to design questions. Hence, questions arise as to how teachers identify these sub-skills to create a learning progression for science inquiry skills and whether there are specific teaching practices which are valuable for developing each sub-skill?

Conclusion and implications

This study investigated the knowledge and practice of science teachers when teaching their students' science inquiry skills to identify how students are supported in their development. Participant responses show that the use of real-life contexts was important for engaging students, whilst simultaneously building their confidence and autonomy. While different approaches were needed to support the learning of distinct inquiry skills, some teaching practices were appropriate for developing multiple inquiry skills. For example, explicit teaching was the primary practice used for developing students' skills in communicating and analysing data, while the provision of templates helped to develop students' skills in writing aims and hypotheses. Modelling was highlighted as valuable for supporting the development of a range of skills.

According to the Australian Department of Education, differentiated teaching, acknowledging cultural diversity, and assessment of students' skill acquisition are important STEM teaching practices (ACARA,2018; Australian Government, Department of Education, 2023), yet there was limited discussion of these strategies by teachers in this study. This implies that these strategies may be less important for teachers, or that they would be included in later years, given that the focus of this study was on year 7 and 8 learning.

The teachers in this study practised a variety of methods for teaching science inquiry skills. However, due to lack of tailored curriculum guidance for teaching these skills, early- career and preservice teachers may instead use limited teaching methods or completely avoid the strand. Therefore, further curriculum development of teaching resources and professional learning (PL) opportunities are required for science teachers who lack confidence in this area. One example of PL for novice science teachers, with limited inquiry or laboratory experience, could be experiencing and practising inquiry with scientists in a real-life research team. Moreover, novice teachers could be supported with one-on-one mentoring / coaching from experienced science teachers to extend and implement the strategies and approaches learnt in initial teacher education, to meet the needs of their current school context. As originally intended, the findings from this study showcased examples of advanced practices by experienced teachers that could be used to design such professional learning activities. To ensure teachers are well prepared to teach science inquiry skills, professional learning must be provided to enhance teacher competence in this area (Crawford, 2014). Initial teacher education needs to include opportunities for pre-service teachers to learn about science inquiry skills prior to commencing teaching, to develop their skills and pedagogical approaches to teaching this important and mandated area of the curriculum.

There are many additional teaching opportunities that align science inquiry skills with other parts of the curriculum. Since these skills span each of the sub-disciplines (e.g., Biology, Physics, Chemistry, Earth and Space Science), they could provide students with interdisciplinary experiences, breaking down the siloed nature of science education. The context-based teaching associated with science inquiry skills can encompass culturally rich examples (e.g., First Nations perspectives) and take advantage of local geographic landscapes, supporting a greater range of student needs in the classroom and provide opportunities to relate to learning outside the classroom (i.e., citizen science). Lastly, there are opportunities for developing students' numeracy skills, through the everyday contexts provided and the skills associated with analysing data. The teaching of science inquiry skills has considerable potential; however, teachers need to be well prepared for and confident in the teaching practices that are valuable for student learning.

About the Authors

Dr Emma Stevenson

Emma Stevenson is a lecturer of science education at the University of Melbourne. Her research involves the learning of teachers and teacher educators in the fields of science and STEM education.

Dr Merryn Dawborn-Gundlach

Merryn Dawborn-Gundlach is a senior lecturer at the University of Melbourne. Her research includes the support required by career-change teachers and developing scientific reasoning competencies of teachers.

Professor Jan van Driel

Jan van Driel is a professor of science education at the University of Melbourne. His research areas include the professional knowledge of teachers and the use of models in science education.

References

ACARA [Australian Curriculum, Assessment and Reporting Authority]. (2018). The Australian Curriculum F-10: The three interrelated strands of science. https://www.australiancurriculum.edu.au/f-10-curriculum/science/structure/

Akuma, F. V. & Gaigher, E. (2021). A systematic review describing contextual teaching challenges associated with inquiry-based practical work in natural sciences education. EURASIA Journal of Mathematics, Science and Technology Education, 17 (12), p. 1-23. https://doi.org/10.29333/ejmste/11352

Anthony, G. & Walshaw, M. (2009). Characteristics of Effective Teaching of Mathematics: A View from the West. Journal of Mathematics Education. 2 (2), p. 147-164.

Australian Government, Department of Education. (2023). Differentiate Learning for Different Levels. https://www.education.gov.au/australian-curriculum/national-stem-education-resources-toolkit/i-want-know-about-stem-education/what-works-best-when-teaching-stem/differentiate-learning-different-levels

Australian Science Teachers Association [ASTA]. (2009). National professional standards for highly accomplished teachers of science (final draft).

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. Science Education, 91(3), 347–370. https://doi.org/10.1002/sce.20186

Capps, D. K. & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: are they happening? Journal of Science Teacher Education. 24, p. 497-526. https://doi.org/10.1007/s10972-012-9314-z

Chen, J., & Cowie, B. (2013). Engaging primary students in learning about New Zealand birds: A socially relevant context. International Journal of Science Education, 35(8), 1344–1366. https://doi.org/10.1080/09500693.2012.763194

Crawford, B. (2014). From Inquiry to Scientific Practices in the Science Classroom. In N. Lederman & S.K. Abell (Eds.), Handbook of Research on Science Education, (pp. 529-556). Routledge. https://doi.org/10.4324/9780203097267-36

Duit, R. (1991). On the role of analogies and metaphors in learning science. Science Education. 75 (6), p. 611-735. https://doi.org/10.1002/sce.3730750606

Gilbert & Justi. (2016). Modelling-based teaching in science education. Springer International Publishing, Switzerland.

King, D. (2012). New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning. Studies in Science Education, 48(1), 51–87. https://doi.org/10.1080/03057267.2012.655037

Kirschner, P. A. (2002). Cognitive Load theory: implications of cognitive load theory on the design of learning. Learning and Instruction. 12(1), 1-10. https://doi.org/10.1016/S0959-4752(01)00014-7

Kruit, P. M., Oostdam, E., van den Berg, E. & Schuitema, J. A. (2018). Effects of explicit instruction on the acquisition of students' science inquiry skills in grades 5 and 6 of primary education. International Journal of Science Education, 40 (4), p. 421-441.

Lederman, J.S. et al. (2024). Completing the progression establishing an international baseline of primary, middle and secondary students' views of scientific inquiry. International Journal of Science Education. 46 (7), p. 715-731. https://doi.org/10.1080/09500693.2023.2256458

Morrison, J. & McDuffie, A. R. (2009). Connecting science and mathematics: using inquiry investigations to learn about data collection, analysis, and display. School Science and Mathematics. 109, p.31–44. https://doi.org/10.1111/j.1949-8594.2009.tb17860.x

National Research Council. (2000). Inquiry and the national science education standards. National Academy Press.

NGSS Lead States (Ed.). (2013). Next generation science standards. The National Academies Press.

Oliveira, A. (2010). Improving teacher questioning in science inquiry discussions through professional development. Journal of Research in Science Teaching, 47, 422 - 453. 10.1002/tea.20345.

Organization for Economic Co-operation and Development (2006). Assessing scientific, Reading and mathematical literacy: A framework for PISA 2006. OECD Publications.

Ortiz, A. M. L. & Aliazas, J. V. C. (2021). Multimodal representations strategies in teaching science towards enhancing scientific inquiry skills among grade 4. Ioer International Multidisciplinary Research Journal. 3 (3), p. 107-118.

Orton T. & Roper T. (2000). Science and mathematics: a relationship in need of counselling? Studies in Science Education. 35, p.123–153.

Osborne, J. (2013). The 21st century challenge for science education. Thinking Skills and Creativity, 10, 265–279.

Osborne, J., Zucker, A., & Pimentel, D. (2023). Tackling Scientific Misinformation in Science Education. https://medialiteracynow.org/wp-content/uploads/2023/05/Tackling-Misinformation-in-Science-Education-Osborne-Zucker-Pimentel.pdf

Prain, V., & Tytler, R. (2012). Learning through constructing representations in science: A framework of representation construction affordances. International Journal of Science Education, 34(17), 2751–2773.

Riordain, M. N., Johnston, J. & Walshe, G. (2016). Making mathematics and science integration happen: key aspects of practice. International Journal of Mathematical Education in Science and Technology, 47 (2), p233-255. http://dx.doi.org/10.1080/0020739X.2015.1078001

Victorian Curriculum and Assessment Authority. (2015). Victorian curriculum: Foundation-10. https://victoriancurriculum.vcaa.vic.edu.au/

Victorian Curriculum and Assessment Authority (VCAA). (2024, 28 March), Science; Structure. https://victoriancurriculum.vcaa.vic.edu.au/science/introduction/structure#:~:text=The%20Science%20curriculum%20has%20two,scientific%20view%20of%20the%20world.

Wong, V., & Dillon, J. (2019). 'Voodoo maths', asymmetric dependency and maths blame: Why collaboration between school science and mathematics teachers is so rare. International Journal of Science Education, 41(6), 782–802. https://doi.org/10.1080/09500693.2019.1579945

Appendix A

Interview Questions for Participating Teachers

1. Can you **describe a lesson** where you have taught some science inquiry skills to year 7 or year 8 students?

Reflecting on this lesson:

- In the lesson that you've just described I noticed that the science inquiry skills were taught in the context of _______ content knowledge. Why did you choose this context?
- In the lesson that you've just described I noticed that you taught the science inquiry skills of ________ by ____________Why did you choose this/these teaching practices?
- In the lesson that you've just described how did you assess your student's science skill acquisition. Why did you choose this/these approaches?
- Were there any challenges during the lesson related to teaching science inquiry skills?

2. More **general questions**:

- What science inquiry skills are focused on in other science lessons? (List from survey questions?)
- What teaching practices have you used to develop other science inquiry skills? (e.g., student designed investigations, teacher modelling, provision & analysis of exemplars)
- What content areas (e.g., physics, chemistry, biology, space & earth science) are useful for developing science inquiry skills in science lessons?
- What teaching practices/ pedagogies do you think engage students in learning about inquiry skills?
- What are the challenges of teaching students about inquiry skills in 7-8 science education?