# Chapter 2
# Pre-Service Teachers Representing Socioscientific Aspects of Scientists' Work

**Peta J. White and Russell Tytler**

**Abstract** Developing learning sequences focused on socioscientific issues often begins with public controversy and introduces a variety of perspectives—economic, local values, political considerations, as well as scientific and engineering research. Many issues can be considered from a post-normal science perspective, where the involvement of the public in the scientific process and the complexity of the science are acknowledged. However, these issues of complexity and attention to public policy can often be part of the driving force behind scientists' work. In this chapter, we describe a project in which pre-service teachers (PSTs) and undergraduate science students worked with science researchers to translate their research, focusing on the nature of their practice including personal commitments, into online learning modules for application in lower secondary classrooms. The aim was to enliven and extend classroom practice through the representation of contemporary science. Several scientists, and resulting learning modules, focused on sustainability issues such as top predators in ecosystems, brumbies in sensitive alpine environments, or frontier materials design focused on sustainable practice. Our contention is that, by focusing on sustainability contexts through the experience of scientists, many of whom are passionate advocates, students can come to learn science through the wider context of a socially responsible agenda. We describe the nature of these classroom materials, the process of their creation, the challenges of translating scientists' work into classroom activity, and the educative potential of this approach for tertiary students and scientists alike.

**Keywords** Scientists · Pre-service teachers · Socioscientific issues · Contemporary science · Secondary school education

P. J. White (✉) · R. Tytler
School of Education, Deakin University, Melbourne, VIC, Australia
e-mail: peta.white@deakin.edu.au

R. Tytler
e-mail: russell.tytler@deakin.edu.au



Y.-S. Hsu et al. (eds.), *Innovative Approaches to Socioscitific Issues and Sustainability Education*, Learning Sciences for Higher Education,
https://doi.org/10.1007/978-981-19-1840-7_2

## 2.1 Introduction

There is growing interest in schools and teachers partnering with community and professional scientific organizations and practitioners as part of an agenda to open the school curriculum to scientific/STEM professional practices in authentic settings (Freeman et al., 2015). In Australia, there have been numerous scientific community partnership initiatives operating across school systems and locally negotiated by individual schools over the last decade (Office of the Chief Scientist, 2016; Tytler et al., 2011, 2017). Research has identified a variety of ways in which scientists and other STEM professionals can work with schools to provide opportunities for students to engage with contemporary STEM practices (Forbes & Skamp, 2013, 2014; Tytler et al., 2015).

There is evidence that such partnerships can engage students in enhanced science inquiry processes; lead to more student-centered pedagogies than normally occurs in classrooms; provide insights into STEM-related careers; and foreground scientists and STEM-related practices in local contexts, often in rural contexts outside the orbit of mainstream professional development arrangements (Grcevich et al., 2015; Tytler et al., 2011, 2017). There is evidence also that both STEM professionals and teachers participating in such arrangements can identify benefits for themselves from their participation (Falloon & Trewen, 2013; Forbes & Skamp, 2013; Tytler et al., 2015; Winters et al., 2013). There is significant evidence that students benefit from interactions with scientists working with their teachers. Our evaluation of a major Australian initiative placing scientists, and more recently a broadened practice that includes STEM professionals, in schools (Tytler et al., 2015) identified positive outcomes for teachers in terms of expanded understandings of the STEM disciplines and how these are practiced in societal settings. Consistent with previous research the pedagogy shifted to more student-centered, responsive teaching and learning. In interacting with scientists, students learnt about possible careers and about scientists' lives—the scientists acted as role models for promoting scientific dispositions—curiosity, energy, and their own commitments which often, in terms of the types of people they were, disrupted traditional views of scientists and their practices (Tytler et al., 2015).

There can be difficulty, however, in such programs where STEM practitioners from a variety of backgrounds are expected to work together and with teachers, involving unfamiliar territory and with limited time to devote to the activity. Several issues have been identified through research into such partnerships (Falloon, 2013; Falloon & Trewen, 2013; Kisiel, 2010) including difficulties in achieving shared understandings of curriculum or to establish effective communication to bridge the gap in such understandings. In the evaluation of an Australia-wide program pairing STEM professionals with individual teachers in schools, while we found a range of very positive outcomes and verified the success of the program overall, two circumstances indicate the limitations of such models in supporting system-wide impact. The first was the identification of issues in a significant minority of partnerships with misunderstandings and unrealistic expectations and misunderstandings, and subsequent collapse attributed to this (Tytler et al., 2015). The other was the long waiting list for scientists—there are simply not enough scientists with time available to achieve coverage with this activity at a system level.

In this chapter we describe an expansion of our interest in school–STEM community partnerships in new directions, in part addressing these issues of clarity of partnership focus, and implementation at scale. These involve three innovations extending traditional partnership models.

First, as part of a project funded by the Australian Government and run in four Melbourne-based universities (Reconceptualising Mathematics and Science Teacher Education Program: ReMSTEP) we linked Deakin University research scientists with PST and in-service teachers, and undergraduate science students, to represent the scientists' work in educational resources. This focus on teacher education represented an attempt to build teachers' understandings of the wider context within which scientists' work occurs and the nature of the work.

Second, we developed a series of models through which PSTs and teachers could interact with scientists and with our research team to produce online modules that represented aspects of contemporary science practice. To ensure access for all, these resources were housed in the website Contemporary Science Practices in Schools https://blogs.deakin.edu.au/contemporary-science-practice-in-schools/teaching-and-learning-resources/lower-secondary/. These modules contain activities that represent key science ideas and practices realized through a scientist's or science team's research. These include videos of the scientist talking about their work, activities introducing and unpacking original data for analysis and discussion, activities designed to stimulate understanding of scientific practices, and readings around the context of the research. Findings regarding the impact of these modules when used by teachers demonstrate eagerness in using such resources and success in engaging students in these important issues (Vamvakas et al., 2021).

Third, many of the case studies of contemporary scientists represented in these modules feature significant interactions between science and societal issues, and increasingly we have been focusing on these resources to promote school engagement with sustainability-related science and with socioscientific issues (SSI). We combine this with serious attention to the nature of the science, and the experiences, motivations, and values of the scientists involved, and their contemporary science practices. We see ourselves as broaching new ground here, in making explicit the role and experience of scientists working in these fields as a way of teaching science concepts and practices through SSIs and sustainability concerns.

There has been increasing interest in and advocacy of inclusion of science–society interactions over the last few decades, resolving in the last two decades into advocacy of curriculum interventions exploring SSIs as a means of enriching and expanding students' scientific literacy to include more complex views of the epistemic processes of science including ethical aspects of science (Zeidler, 2014), values inherent in and impacting on scientific practices and interactions with societal contexts, and argumentation in the context of different forms of evidence in these interactions (Dawson & Carson, 2020; Sadler, 2004; Tytler et al., 2001). However, SSI curricular interventions have not generally achieved strong representation in mainstream curricula, and research tends to focus on boutique innovations rather than the widespread uptake of SSI curricula at system level, partly because of teacher focus on traditional science curricular values, concerns about student performance on tests (Klosterman & Sadler, 2010) and associated concerns about curriculum crowding, and lack of access to resources (Vamvakas et al., 2021). In our research we aim to provide a natural home for SSIs in the mainstream science curriculum by linking these with resources focused on contemporary scientific practice in societal contexts, in which scientists themselves are engaged in socioscientific challenges and issues.

The questions we address in this chapter are:

1. What are the outcomes for PSTs and undergraduate students producing educational resources through working directly with scientists?
2. What models of PST/teacher interactions with scientists can lead to effective representation of scientific practices in school resources?
3. What are the possibilities and the justifications for introducing school resources at scale that combine engagement with contemporary science and scientists and their involvement with socioscientific issues?

In responding to these questions, we first review our approach, then focus on a small number of cases of module production featuring scientists researching in contentious sustainability-related areas.

## 2.2 Working with PSTs and Teachers to Represent Scientists' Work

The ReMSTEP project offered the opportunity to explore ways to link PSTs with inspiring examples of STEM research and development, to illustrate how these can be translated into school activities, and to offer examples of how they as teachers might interact with the STEM community. We explored a range of models through which this interaction could occur, with the common feature that PSTs (and in some cases teachers, and undergraduate science students) were paired with a scientist, with the intention of interpreting and representing their research in school resources. The approach and overall findings have been described previously (Raphael & White, 2021; White and Raphael, In press; White et al., 2018); here we paraphrase the different models with emphasis on the societal links and particularly the representation of scientists working on socioscientific issues.

Stem cell exploration: This involved a Stem Cell researcher working with three PSTs supported by two teacher educators to develop resources which included a drama pedagogy exploring a variety of stakeholder perspectives on stem cell access and stem cell tourism.

In terms of representation of the science of STEM cell research, the scientist was clear about the need to represent contemporary understandings of stem cell research to the public.

> If anyone is interested in finding out about stem cells, it can be a real challenge. There is a lot of information available online. But a lot of it is either over-hyped, very simplistic, and you even see this in the media. A lot of people draw their information from the media. We have to go well beyond the media and get behind the headlines. In this project, we have tried to arm both teachers and students with a more reliable source of information. (Scientist)

The PSTs involved in this project had strong science backgrounds but appreciated the opportunity to translate contemporary science and the passion of scientists into the classroom

> I look at prescribed curriculum differently as I now think that there is a lot more flexibility in there to teach creatively, to go on tangents, and to explore the scientific skills outside the key knowledge. (PST)

During the period of putting together this learning sequence the controversy around embryonic stem cells was somewhat resolved with the application of pluripotent stem cells. An SSI that emerged, however, was that of stem cell tourism (where patients travel to other countries to receive stem cell therapy/treatment). The learning materials developed focused on a science–drama pedagogy (Raphael and White, 2021; White and Raphael, In press) where students enrolled in stakeholder positions and debated the issue in a scene from a TV show (something like the ABC's Q&A https://www.abc.net.au/qanda/). The result was two sequences that consisted of the themes: contemporary understandings of stem cells and stem cell research; a profile of a passionate, leading stem cell researcher; and controversial issues around stem cells therapy.

Multimedia resource production: Students were prescribed an assessment where they were to select a locally relevant environmental issue (with social implications) and develop a three- to five-minute multimedia (video) presentation.

The focus was on resource generation with multimedia skill refinement as well as deeper exploration of local issues that connected to the curriculum. Students were also invited to develop interview skills as they conducted and then used interview sequences to explain the science and the implications. Students selected their own issue and sourced their own scientist. Finding the right scientist proved difficult for many. In most, the scientist was successful in representing the knowledge about the issue with clarity while also interpreting the impact the issue represented for all. The resulting resources were ready for use in a classroom, designed to engage and interest as well as inform and involve students.

Contemporary science workshops: Based on the success of PSTs interacting with scientists, and of the learning sequences that resulted from these structured interactions, the team trialed a process that brought together scientists with PSTs, in-service teachers and the development team, and other colleagues more directly. This involved running workshops (two workshops produced several learning sequences) in which scientists were invited to participate and present their work, bringing along several research artefacts (a presentation, papers, information on the science ideas, media cuttings).

In the first workshop we matched scientists with PSTs and teachers. The scientists initially presented their research and were questioned by the educators. The process then shifted to workshopping ways that the research might translate into school science activities. This required a deeper knowledge about the curriculum opportunities and pedagogical practices/approaches. At the end of the day, the products were variable, with some groups preparing near-finished sequences with resources, while others only the beginnings of ideas. During the day, the scientists were taken aside to be interviewed about their research. These were edited to produce five- to eight-minute resources that provide insight into the scientist's motivations, their passion for researching in the area, and the nature and purposes of the research. These videos are used as resources in classrooms to provide examples of science as a human endeavor (one of the curriculum strands with specific outcomes).

Both the scientists and educators were positive about the day:

> Really worthwhile exercise. One of the reasons the utility and excitement of science does not reach school children is that the teachers of science subjects have never worked in the field … Thus, having a scientist to contribute means that the problem of teachers being disconnected with the science discipline is solved at least to some extent. (PST)

> It is always interesting to see which of my findings are generally interesting to others. Also, because I do very little teaching, it is illuminating to learn what approaches teachers think will work best with students. (Scientist)

Following these initial actions, several learning sequences were refined by the research team and are available on the project website (see above). These include a sequence on the science of nanotechnology, in which the scientist raises a range of issues about the responsible development of nanotech processes and the longer-term dangers and ethics regarding unregulated research in the area impacting the environment and involving a variety of stakeholder groups. As with the stem cell sequence, we see an example of the bringing together of contemporary science research, the incorporation of societal issues as an important aspect of the researcher's focus, and the involvement of multiple stakeholders in the research outcomes.

The second workshop involved a strong thematic focus on environmental issues relevant to our region and a similar mix of participants. The scientists presented to an open (public) forum in the morning prior to the afternoon with invited participation in small group curriculum planning. In the afternoon session, groups reported on their progress and ideas were contributed by the wider group. Following this event, science students worked further on the sequences, supported by the research team. The focus of the presentations were:

- Conflict materials (the production of which was used to fund conflicts in a range of countries) and described ethical principles represented in scientific research establishments avoiding such materials in their research;
- Changing patterns of migratory bird routes as a result of wetland disappearance and climate change impacts;
- Ecosystem research around the potential impact of the reintroduction of dingoes into a national park, the controversy with objection from local landowners, and the use of social media to scaffold useful discussion in the community; and

- Advocacy for the culling of feral horses from alpine areas based on extensive research into their impact on local environments and species, strategic actions, and arguments developed by a range of stakeholders.

All sequences required considerable input from the research team to scaffold and further develop the pedagogical strategies applied to the contemporary issues.

Community science project: A further variation of these models was applied in an undergraduate science course (as a collaborative project for an external client—our research group was the external client). Scientists were invited to participate to have their research 'extended' and communicated in classroom contexts. The intended outcome was to be a teaching and learning sequence relevant for the lower secondary classroom. Again, a public symposium was held in the morning and then a workshop afternoon with in-service teachers and our research team working with the scientists and science undergraduates to develop the classroom materials. To exemplify, we focused on three projects that illustrate this combination of representing the nature of contemporary scientific research, scientists' lives and motivations, and their engagement with societal needs and perspectives.

Three projects are exemplified: the effects of 'brumbies' (feral horses resulting from a previous era of mountain cattle grazing) on alpine flora and fauna, the effects of reintroducing dingoes (wild dogs) to ecosystems to re-equilibrate populations; and carbon sequestration possibilities in marine ecosystems. Each project was currently researched in our local region and included obvious social and environmental impacts.

## 2.3 The Impacts on PSTs and Undergraduate Students

Interviews with these undergraduate students concerning their experience, and their intentions in developing the school resources, highlighted several themes:

- The value of representing scientists as normal relatable people, who are passionate about their work and the impacts of their work:

> [With regard to the scientist], we wanted to highlight a relatable aspect of who he was. He told a story of how he was always interested in ecology, he'd go to the beach and play around in the rock pools while everyone else was body boarding. He was just poking anemones. I was exactly the same when I was a kid and here I am finishing my science degree, so we really wanted to highlight that he is not some–or science in itself is not just some weird side thing that only super smart, nerdy people do. That it's just a pretty normal thing and even stuff like poking around in rock pools is the beginning of science. (Undergraduate student 1)
>
> I really liked hearing from the scientists and just how passionate they were about … conservation and the science … when they start talking about it and how their face just lights up. (Undergraduate student 2)
>
> Just in general terms how excited scientists are about their science. I don't think there's a researcher in the world who you could ask, 'So tell me about your work,' and they wouldn't light up like a Christmas tree. They're all so excited about what they're doing,

> which is awesome because I don't think anyone wants a career they're not excited about. (Undergraduate student 1)

- The nature of contemporary or current scientific research with its vibrancy, importance, and local relevance for all (socially relevant):

> It's just really opened my eyes more to the science research side of the community. (Undergraduate student 2)
>
> I think what really needs to be more integrated into the curriculum is the nature of fieldwork. (Undergraduate student 1)
>
> … it is a very collaborative process, it's not an individual conducting these things … that's what I learned about scientific practice. (Undergraduate student 2)
>
> Learning that there are so many people out there flying under the radar, doing all this amazing work; I think that was the biggest learning part for me (Undergraduate student 2)

Creating the context of contemporary science within the classroom gives the content its purpose. Rather than just being:

> 'This is what other people have found out', it's: 'This is what people are doing now. This is what's important and this is why they're learning it' (Undergraduate student 2)

- The value of representing science in real-life contexts to engage students:

> I think it's been a lesson to me that contemporary science can have a huge impact on student learning and student engagement in the content. (Undergraduate student 3)
>
> But now I think I definitely have more confidence in saying, 'Actually here's the content. This is how it's applicable to real life,' and yes, I think that's really valuable to learn for a pre-service teacher. (Undergraduate student 3)
>
> I think the education system until recently didn't sort of harbor curiosity and critical thinking. ... I think if we want better scientists and more people being interested in science as they grow up, we need to be teaching people critical thinking from the get go. (Undergraduate student 1)

- The importance of representing societally important issues associated with learning about contemporary scientific practice, and developing the tools in students to engage with this:

> Researching the Conversation website because [scientist]'s got a few articles on there and then there's links to other articles and it's like, 'Oh my God, there are so many people with the same concerns.' That's really good to see and it does make you more passionate, you want to do more. You want to let the kids know about it, you want to spread the word I guess. (Undergraduate student 3)
>
> That's what I'd want to do in any context. Is incorporate contemporary science and say, 'Okay, what about this issue?' and say to kids, 'Have you heard about this?' And I suppose give them the question and give them the tools that they need to come to these conclusions that, 'Oh wow, if we lose our native species, it's going to have a huge impact on our ecosystems'. (Undergraduate student 3)
>
> Just learning about climate change and how big it really is because I think people always know it's happening but it's so big that they're like, 'Ah, one person can't change that.' So really putting that into perspective that well you can, you can be a part of this and you can change it and that one person that one effect. (Undergraduate student 2)

These undergraduate science students (at least one intended to become a teacher) were clear that they had learned a lot from interacting with the scientists and designing ways to engage young people in the science and associated issues that extended the views of science and scientific practice beyond what they had learned in two years of an undergraduate degree. The device of interpreting the research for school students arguably focused their attention on what they themselves gained from the interaction, and this included the themes we are foregrounding in the project; the nature of contemporary scientific practice, the commitments and purposes of scientists, and the strong links of much of contemporary research to societally important and often controversial issues.

## 2.4 The Scientists' Considerations and Involvement

The scientists were clear about their motivations for being involved in the project; first, to promote the importance of the messages they were passionate about and that drove their research; and second, to 'bridge the gap' between the scientific community and the public through clarity of communication of the research perspectives on important societal issues.

Pest Species Scientist:

> I think that is one thing that really …that should be encouraged, real scientists working with students and teachers so that we can bridge that gap between scientists and the public in general because there is such a huge gap at the moment and to kind of humanize scientists I think is really important. This is a really good step in that direction.

Landscape Ecologist and the population decline of the Baw Baw frog:

> I was trying to emphasize things that I think are particularly important for ecology and conservation, raising their level of knowledge of what I thought was important and trying to convince them that some of the data and evidence that I've collected in various projects can be used to tell a more sophisticated story. It's not just a food web story, it's a story about threats to species and ways that they might be conserved.
>
> The point of the project is to try to get what is high level science across at a level that students in year eight or year nine could understand … that it's always a learning process to challenge yourself to communicate with someone from a different field with a different background with different motivations, so that enriches my capacity for communication … to be able to show that you're able to communicate to an audience other than your scientific peers. That's an important skill that a lot of employers are going to be looking for.

Ecologist—reintroduction of top predators:

> I think the key points are really generating understanding of the importance of these animals in the landscape and in the environment. Humans have a fairly uneasy relationship with many predators.
>
> Many people within my field are really in the area of research that we are because we feel deeply passionate about trying to manage the environment better and really hopefully see it in better shape than it currently is and certainly hope that it doesn't get any worse. I

> think conveying that passion and how science can really help inform decision making and affect our lives and probably demystify … who scientists are.
>
> People can find out facts and figures and so forth, but I think really telling people the story about you in the field and things that happened and the journey and why you are even doing that research in the first place, what motivates you.

The interview data, and consideration of the quality of the science and associated societal issues embodied in the resources, show the mutual learning and enthusiasm of students and scientists alike. PSTs gained a clear picture of the role of sustainability contexts and socioscientific issues in framing these research scientists' work, and their involvement in public debate on these issues. They were highly engaged with this extension of their view of the nature of scientific research practices, and enthusiastic about similarly engaging school students through these resources.

## 2.5 The Production of Resources for Schools

Thus far in the project, PSTs and undergraduate science students have produced, with considerable research team support, several modules on integrative ecology as well as many other topics including: scientific modeling using scientific papers on osmoregulation in fish; the science and environmental impact of microplastic nurdles; nanotoxicology; conservation options for endangered Tasmanian devils; scientific field work and a debate on ethics of scientific research associated with an endangered frog; a 'top predators' module involving monitoring and restoration of ecosystems, including interpretations of a contemporary scientific publication; energy research and the circular economy; battery technology research; and many more. Each module is linked to a particular aspect of the secondary school curriculum and includes representations of scientists and their work, often through video. These resources are listed on the Contemporary Science Practices in Schools site—Lower secondary https://blogs.deakin.edu.au/contemporary-science-practice-in-schools/teaching-and-learning-resources/lower-secondary/.

A key theme with all these modules is the representation of contemporary local research and researchers, both as sites for introducing or extending key concepts and scientific practices, and for articulating the societal context of the research. This latter theme is very often linked to sustainability issues, and the modules raise questions about the importance of science in achieving sustainable practice, about scientific research ethics, and in some cases the entanglement of scientific research with controversial or contested issues. Science is thus presented in many of these modules as benign and rational, often reflecting the views of the PSTs and their acceptance of the scientists' own enthusiasms. However, in some modules there are elements of post-normal science (Ravetz & Funtowicz, 1999), with the scientific work entangled with public debate and questions of value underpinning research directions and policy. Often this is elaborated through the application of pedagogical activities or strategies that entangle the students' perceptions with the practices of the science.

It is our contention, and our experience (described in White et al., 2018), that in pursuing this work the PSTs benefit by their serious engagement with contemporary research and its societal enactment, and with the scientists (via video or in person), and that this will hopefully enhance their practice as future teachers. Further, we have some evidence (Vamvakas et al., 2021) that the modules themselves have the capacity to engage school students in learning about the practices of science in contemporary contexts and its human nature, and in engaging with scientific inquiry processes as part of this. It was clear that the activities were engaging and very educative for both students and teachers, but also challenging for teachers not accustomed to the detailed analysis involved in unpacking the research, or to managing debates about scientific ethics that relied on unpacking students' personal thoughts, feelings, and expressions (and their own).

The role of the teacher in scaffolding and adapting the resources was crucial for their successful implementation. We argue that the modules can be powerful vehicles for student consideration of SSIs within the context of the societal and sustainability entanglement of much contemporary scientific research. We propose that, rather than treating SSIs as a separate activity from core programs of learning scientific concepts and practices, they are more powerfully included in the curriculum as associated with scientists' core practices. This position derives in part from the fact that many scientists are themselves advocates of societal or legislative change, and their research is driven by, and informs wider societal agendas. We also argue that the presentation of SSIs as inquiry learning packages with the inclusion of the scientists (often via video) generates a more palatable or approachable resource or learning tool for teachers.

In fact, most modules developed by PSTs do not include a thorough focus on both the scientific concepts and practices and socioscientific considerations that can accommodate a serious consideration of SSIs or 'socially acute questions' (Morin et al., 2017). We are currently working on a research proposal for a more thorough integration of these themes and describe here how this might occur, using two of the example topics described above: 'top predators' and 'feral horses'. In this proposal we draw on existing frameworks for the three themes as follows:

Scientific practices: We draw on the New Generation Science Standards—science and engineering practices (NRC 2012) applied to working within contemporary science settings: asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information. This aligns with our National Curriculum (ACARA, 2021) in the area of Science Inquiry providing useful outcomes to address through engaging learning experiences.

Science as a human endeavor: We draw on the two strands of the Australian Science curriculum: Nature and development of science (the use of evidence to build, revise, refine and extend knowledge, and the individual and collective work of scientists); Use and influence of science (by, and on individuals and communities, decision-making and responses to issues).

Socioscientific reasoning: We draw on the framework of Morin et al. (2014, 2017), identifying six dimensions of socioscientific sustainability reasoning ($S^3R$): problematization; interactions; knowledges; uncertainties and risks; values; and regulation. This framework can guide the characterization of different types of socioscientific issues associated with scientists' research, from the situating of research in societal settings, to issues associated with ethical research agendas, or uncertainty of the science or its application, to issues that can be characterized by 'socially acute questions' that focus sharply on conflicts involving different stakeholders, values, knowledges, and regulatory settings.

## 2.6 The Structure of the 'Top Predators' Sequence

This sequence consists of three modules (https://shenaeryan31.wixsite.com/predators). The first explores the concepts of trophic cascade and keystone species through structured activities based on video presentations. The second explores food webs and the role of dingoes, again based on videos of contemporary activity and research, and a structured game illustrating these concepts. The third module takes students through a structured interpretation of a scientific paper where they interpret real data in the form of graphs to make sense of trophic relations and evidence for the impact of top predators on different populations in an ecosystem. In the video, the scientist presents an argument for reintroduction of dingoes, and discusses opposition from other stakeholders, but this is not translated into the SSI activity that would have been powerful at this point.

From the point of view of scientific practices, the module is rich in: asking questions and defining problems; developing and using models (trophic models); analyzing and interpreting data; using mathematics in interpreting data; constructing explanations, engaging in argument from evidence; and evaluating and communicating information. Similarly, the module is rich in consideration of Science as a Human Endeavour in terms of the way evidence is generated by multiple scientists to scope the local ecology, and the use of this knowledge to propose solutions to the current imbalance. Armed with these knowledges, a class consideration of the question 'should dingoes be reintroduced' would elicit rich discussion of not only the science but of the different perspectives that define the problematization, competing values and interests, represented by local farmers, tourist interests, and the local indigenous owners, of the different knowledges that would be brought to bear, of the short and long term interactions in the eco-social system, and of the uncertainties and risks involved. Further consideration of modeling, and of the design of solutions based on evidence, would also be triggered by serious consideration of this question.

## 2.7 The Structure of the 'Feral Horses' Sequence

This sequence involved the scoping of the feral horse issue through videos representing the views and evidence from the scientist Professor Don Driscoll, presented at the workshop described above, and videos representing the views of the heritage horse association, the 'Alpine liaison committee', and an interview sequence of different stakeholders (https://damonfarrugia.wixsite.com/website-1/feral-horses).

The activity involves students nominating a view along a scale, then considering the evidence and justifying their position in debate. As with the possible $S^3R$ dimensions outlined for the previous case, this issue has a richness of values and stakeholder interests as well as high stakes policy debate, to engage students with the role of science alongside multiple interests, values, and knowledges involved in such a question. From the workshop video there are rich possibilities for considering the Science as a Human Endeavour theme, involving personal commitments, publications and social media use, and an unfolding story of evidence generation. In terms of scientific practice, this involves field studies of damage to local environments, evidence against this being caused by feral deer rather than horses, evidence arguing for air culling as the most humane control method, and modeling of damage levels with different population densities. The topic, and the data encapsulated within the resource, thus offers the possibility of a more comprehensive resource that combines the three themes in ways that interact productively, and our proposal is to extend the resource in these directions.

## 2.8 Conclusion

### *2.8.1 Models of Effective Interaction for Future Teachers Working with Scientists and Contemporary Science*

The trajectory of model development was incremental, although not linear. As we developed refined focus on how to manage the interactions between scientists and PSTs or in-service teachers, we refined the processes. We were able to generate curriculum resources, video of scientists describing their values, multimedia resources about environmental issues, public workshops or symposia, and other workshop events and opportunities. Over time more focused pedagogies such as using data from published scientific papers as a secondary data source for student analysis were refined. The nuanced and refined strategies took time and feedback from various sources to develop. Conference presentations to teachers and metrics from website access has evidenced the interest in the tools and strategies.

The curriculum resources offered engaging and challenging activities that open fresh perspectives on the nature of contemporary scientific research, often involving ethical concerns or implicit value positions around sustainability themes. The scientists themselves are driven by such themes and concerns and were engaged in public advocacy of socioscientific positions. The resources also contain activities involving analysis and discussion around evidence from scientific publications, engaging teachers and students in authentic scientific practices beyond what is normal in classrooms. Thus, for PSTs, engagement with contemporary scientists in this way has expanded their views about contemporary scientific practices, about the human aspects of scientific endeavor, and about the entanglement of science and scientists with societal issues.

### *2.8.2 Scaling up the Development and Application of Curriculum Resources*

The development of these curriculum resources is intensive, yet it yields more than just the final product. The capacity building in those involved is a key element. Communicating these products and the process has generated interest in other teachers. This multi-faceted approach is aligned with curriculum reform and innovation from the school system (State Curriculum) to the classroom. Thus, scaling up implies not only the provision of access to the curriculum materials to anyone interested, but also the capacity building of teachers and future teachers who value and have well-developed skills in generating future teaching and learning programs. Additionally, working with the scientists to focus their energy on the development of science communication tools will enable teachers to generate learning experiences more easily. The use of video and multimedia resources including animations has been an integral step.

Secondary science teachers can find it difficult to incorporate contemporary science, or argumentation about scientific issues into their practice, largely because of curriculum crowding, pressures of mainstream assessment, lack of access to scientists, and lack of resources (Vamvakas et al., 2021; see also Chapter 7). These contemporary science modules have engaged both teachers and students in significant scientific practices and discussions, providing some confidence of the value of representing scientists and their research in this way. While video representation cannot replace the personal impact of face-to-face interactions between scientists, teachers, and students, these resources have the advantage not only of representing a scalable experience of scientists and their practice without drawing unduly on scientists' time, but also, they allow a deliberate focus on aspects of practice that link to the curriculum and can be interpreted at a level appropriate for schools to engage with.

This research has been conducted over a seven-year period and could only have occurred with the regular input of small research grants that were used to facilitate workshops and support researcher focus on curriculum resource development. Generating high quality teaching and learning material is intensive work and requires the application of science and curriculum knowledge with pedagogical experience. The involvement of PSTs and in-service teachers in this process has resulted in not only useful resources to share widely, but also the increased capacity and desire for current and future teachers to find ways to engage contemporary science and scientists in their classroom activities.

We argue that focusing on contemporary scientific practice in this way potentially offers a rich and engaging curriculum experience for students that 1) introduces key concepts in authentic and meaningful settings, 2) provides an enriched perspective on scientific practice and on the human nature of scientists' work, 3) represents in a natural but powerful way the entanglements between science and society through the lens of the purposes and motivations of the scientists themselves, and 4) offers the possibility of supporting students' reasoning about socioscientific issues through a deeper interaction between scientific practices and values and the multiple interests, knowledges, and values of diverse stakeholders that the scientific community themselves uniformly engage with. Finally, the result is a more engaging science program for our students which will hopefully bring about an informed citizenry who can make the necessary decisions that will be required in our near future.

## References


ACARA. (2021). Australian Curriculum and Assessment Reporting Authority. Retrieved from https://www.australiancurriculum.edu.au/

Dawson, V., & Carson, K. (2020). Introducing argumentation about climate change socioscientific issues in a disadvantaged school. *Research in Science Education, 50*(3), 863–883.

Falloon, G. F. (2013). Forging school-scientist partnerships: A case of easier said than done? *Journal of Science Education & Technology, 22*(6), 858–876.

Falloon, G., & Trewen, A. (2013). Developing school-scientist partnerships: Lessons for scientists from Forests-of-life. *Journal of Science Education & Technology, 22*(1), 11–24.

Forbes, A., & Skamp, K. (2013). Knowing and learning about science in primary school 'Communities of Practice': The views of participating scientists in the MyScience project. *Research in Science Education, 43*(3), 1005–1028.

Forbes, A., & Skamp, K. (2014). "Because we weren't actually teaching them, we thought they weren't learning": Primary teacher perspectives from the MyScience initiative. *Research in Science Education, 44*(1), 1–25.

Freeman, B., Marginson, S., & Tytler, R. (Eds.). (2015). *The age of STEM: Policy and practice in science, technology*. Routledge.

Grcevich, J., Pagnotta, A., Mac Low, M. M., Shara, M., Flores, K., Nadeau, P. A., ... & Zachowski, M. (2015, January). Preparing new Earth Science teachers via a collaborative program between Research Scientists and Educators. In *American Astronomical Society Meeting Abstracts #225* (Vol. 225, pp. 240–304).

Kisiel, J. F. (2010). Exploring a school-aquarium collaboration: An intersection of communities of practice. *Science Education, 94*(1), 95–121.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues-based instruction. *International Journal of Science Education, 32*(8), 1017–1043.

Morin, O., Simonneaux, L., Simonneaux, J., Tytler, R., & Barraza, L. (2014). Developing and using an S3R model to analyze reasoning in web-based cross-national exchanges on sustainability. *Science Education, 98*(3), 517–542.
Morin, O., Simonneaux, L., & Tytler, R. (2017). Engaging with socially acute questions: Development and validation of an Interactional Reasoning Framework. *Journal of Research in Science Teaching, 54*(7), 825–851.
National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. National Academies Press. https://doi.org/10.17226/13165.
Office of the Chief Scientist. (2016). *STEM Programme Index 2016*. Australian Government. Retrieved from http://www.chiefscientist.gov.au/2016/01/spi-2016-stem-programme-index-2016-2/
Raphael, J., & White, P. J. (2021). Transdisciplinarity: Science and drama education developing teachers for the future. In P. J. White, J. Raphael, & K. van Cuylenburg (Eds.), *Science and Drama: Contemporary and creative approaches to teaching and learning* (Chapter 9). Springer.
Ravetz, J., & Funtowicz, S. O. (1999). Post-normal science: An insight now maturing. *Futures, 31*, 641–646.
Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513–536.
Tytler, R., Duggan, S., & Gott, R. (2001). Dimensions of evidence, the public understanding of science and science education. *International Journal of Science Education, 23*(8), 815–832.
Tytler, R., Symington, D., & Clark, J. C. (2017). Community-school collaborations in science: Towards improved outcomes through better understanding of boundary issues. *International Journal of Science and Mathematics Education, 15*(4), 643–661.
Tytler, R., Symington, D., & Smith, C. (2011). A curriculum innovation framework for science, technology and mathematics education. *Research in Science Education, 41*, 19–38.
Tytler, R., Symington, D., Williams, G., White, P., Campbell, C., Chittleborough, G., Upstill, G., Roper, E., & Dziadkiewicz, N. (2015). *Building productive partnerships for STEM education: Evaluating the model and outcomes of the Scientist and Mathematicians in Schools program.* Deakin University.
Vamvakas, M., White, P., & Tytler, R. (2021). Contemporary science practice in the classroom: A phenomenological exploration into how online curriculum resources can facilitate learning. *International Journal of Science Education, 43*(13), 2087–2107.
White, P. J. & Raphael, J. (In Press). Drama for teaching controversial issues in science. In D. McGregor (Ed.), *Researching Learning Science Through Drama: Exploring a Range of International Perspectives.* ESERA Book Series. Springer.
White, P., Tytler, R., & Palmer, S. (2018). Exploring models of interaction between scientists and pre-service teachers. In S. Dinham, R. Tytler, D. Corrigan, & D. Hoxley (Eds.), *Reconceptualising maths and science teacher education* (pp. 92–110). ACER press.
Winters, J. M., Jungblut, D., Catena, A. N., & Rubenstein, D. I. (2013, December). Field-Based Teacher Research: How Teachers and Scientists Working Together Answers Questions about Turtle Nesting Ecology while Enhancing Teachers' Inquiry Skills. In *AGU Fall Meeting Abstracts* (Vol. 2013, pp. ED14B-04).
Zeidler, D. L. (2014). Socioscientific issues as a curriculum emphasis: Theory, research, and practice. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 711–740). Routledge.

**Peta J. White** is a senior lecturer in science and environmental education at Deakin University, Melbourne, Australia. She has educated in classrooms, coordinated programs, supported curriculum reform, and prepared teachers in several jurisdictions across Canada and Australia. Her PhD explored learning to live sustainably as a platform to educate future teachers. Peta

continues her commitment to initial teacher education leading courses, units, programs, and in-service teacher education through research-informed professional learning programs. She was recently acknowledged as a Senior HEA Fellow. Peta's current research follows three narratives: science and biology education; sustainability, environmental, and climate change education; and collaborative/activist methodology and research.

**Russell Tytler** is Alfred Deakin Professor and Chair in Science Education at Deakin University, Melbourne, Australia. He has researched and written extensively on student learning and reasoning in science. His interest in the role of representation as a multimodal language for reasoning in science extends to pedagogy and teacher learning. He researches and writes on student engagement with science and mathematics, socioscientific issues and reasoning, school-community partnerships, and STEM curriculum policy and practice. His current interest is in interdisciplinarity leading to critical and creative reasoning. He is widely published and has been chief investigator on a range of Australian Research Council and other research projects.