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IMPLICATIONS FOR THE FUTURE

In this chapter we review the main themes that have driven previous chapters in the book, concerning the nature of the representation construction pedagogy, the theoretical underpinnings of the approach, and what RILS has achieved concerning student and teacher learning. We focus on three main questions that drive the three sections of the chapter:

1. What are the implications of the approach, and of the research findings, for science curriculum policy?
2. What further research is needed to explore the approach in wider contexts such as different cohorts of students and different aspects of science learning?
3. What are the key issues for teachers and for systems in scaling up the approach?

THE IMPLICATIONS OF THE RESEARCH FINDINGS FOR CURRICULUM POLICY

The pedagogy explored and promoted in this book has significant implications for both how school science knowledge is conceived and for the classroom processes by which quality learning is supported. The research program has produced evidence, involving video records, student artefacts, pre- and post-test findings, and teacher testimony, that the approach leads to quality learning and knowledge of key science concepts. From a curriculum perspective, the research throws up the challenges of how to effectively articulate for teachers the nature of quality learning and of the pedagogy that supports this, and how to reflect these approaches to science teaching and learning in curriculum documents and resource policy. In this section of the chapter we will explore four dimensions of this challenge: a) how to characterize and support quality learning in science, b) the implications of the approach for assessment policy, c) the implications for conceptualizing curriculum progression in science, and d) the effective use of technologies implied by the approach.

These challenges, of course, also have implications for the ongoing research program surrounding representation construction and learning.
Supporting Quality Learning

Quality learning is characterized in this research as involving the imaginative construction and coordination of representations to solve problems and develop explanatory accounts in science. This constitutes a more active view of the process of learning science than in traditional accounts of knowledge acquisition, or in customary practice. It constitutes a challenge also to traditional views of the products of learning. The pragmatist semiotic perspective we have adopted takes knowledge as being constituted within representational practices, rather than thought of as command of resolved conceptual structures. The sociocultural turn underpinning the approach treats quality learning as involving participation in a classroom community of practice, where disciplinary literacies become the focus in a public process of generating, challenging, refining, justifying and judging explanations, processes and methods in science.

The classroom processes implied by this perspective on quality learning include:

- The introduction, negotiation, and coordination of a range of representational modes
- The explicit discussion of representations and their role in learning and knowing
- Extended class discussion where ideas are negotiated, and the teacher acts as an intermediary between student-generated representations and the canonical representations of the scientific community

The approach places demands on the pedagogical skills of the teacher in running open discussions and in developing the insight needed to guide the classroom tasks and conceptual negotiation. It also involves an epistemological shift for teachers as they begin to appreciate the active role of representational work in shaping reasoning and learning.

The approach has implications for teacher learning and support, for curriculum framing, and for assessment, all of which will be discussed in subsequent sections. It has implications also for the design of curriculum resources, including the way learning and knowing is characterized in curriculum documents and in text books and other resources.

Chapter 3 described how teachers in the forces unit needed to alter their text-book based practice of a ‘run through’ of a multitude of force types where force conventions were used in an unproblematic, taken-as-given way. The implications of the approach for text book and other resources need further exploration, but we would suggest that there needs to be a more in-depth approach that focuses on core representational competencies, with embedded tasks that involve representation construction, and reflection/discussion of a meta-representational nature. For curriculum framing, the traditional run-through of syllabus topics needs to be trimmed to focus on major ideas, and these expressed in a way that acknowledges their representational, knowledge-in-use nature, rather than as verbal conceptual statements, as is currently
the case. The discussion of curriculum accounts of conceptual progression will be discussed below.

Assessing Learning in Science

One of the key features of the representation construction approach is the way that formative assessment is embedded within the pedagogy, arising from the central element of public (or small group) disclosure of students' ideas and negotiation and refinement of these in the classroom 'community of practice'. Thus, both the teacher and other students have access to these emergent ideas and are part of the process of evaluation of adequacy and subsequent co-construction of refined representations. The other feature of the approach relates to the multi-modality of the representational generation and coordination. This has the dual effect of demanding clarity of students as they respond to the particular affordances of each representation, and opening to scrutiny by the teacher and class their use of representational resources in making claims.

From the teachers' perspective, the approach demands ongoing judgments and negotiation of these emergent ideas, and the response is necessarily complex and contingent. We have pointed out the inadequacy of current formulations of formative assessment as the identification of 'gaps' and the design of tasks to bridge these. Learning through a representation construction process, and we would argue any teaching and learning process, is more complex than this, because the ideas are emergent and multi-faceted and the target flexibly conceived. Teachers' responses are framed within an emergent practice, rather than being concerned with filling a uni-dimensional gap between student and target conceptions.

The challenge for the teachers is thus two-fold. First, making judgments about the quality of student constructed representations, which may be extremely varied, and about their potential for effective claim-making, is a demanding task requiring insight into the conceptual territory. Second, the management of discussion and ongoing tasks may require complex judgments by the teacher. The approach demands, therefore, good subject content knowledge and also pedagogical skills beyond those needed for transmissive approaches. The benefits, however, for student learning, are considerable. The issues associated with teacher learning are discussed in a later section of this chapter.

There is a number of implications for summative assessment. First, our work has demonstrated the richness of student responses when they are encouraged to use multi-modal representations. This implies the possibility of more insightful and valid assessment of student capabilities based on multi-modal responses. We have demonstrated an advantage in encouraging students to respond to questions using multiple representations across modes, through the devices of developing an expectation that this should occur, framing questions appropriately, and leaving sufficient unlined space for students to respond. The difficulty, however, is the extra load in making reliable, defensible judgments when faced with the inevitably varied
responses. There is a need to develop processes for making such judgments. We have argued that quality of student responses is lifted, resulting from the teaching and learning approach and also the opportunity to respond multi-modally. High level responses effectively coordinate the different representations used.

There is evidence that representational capability is being increasingly acknowledged in framing curriculum and assessment. Working with and coordinating representations is part of the new Australian Science Curriculum. The PISA assessment of scientific literacy recognizes student representational knowledge and capabilities as part of its framework. There is thus a need to research the dimensions across which we might think of representational competence, and how to assess these.

*Implications for the Framing of Curriculum Progression*

Framing learning progressions in science curricula has always been problematic because of the organization of content into so many topics, each of which involves different concepts and contexts. The difficulty of application of ideas depends critically on context. Thus, a content sequence that moves from physical to chemical change can be read as a progression in ideas, but in fact there are everyday contexts of physical change that require the use of ideas succeeding those needed to understand everyday chemical change. Contexts bring their own conceptual demand. To frame curriculum in a defensible way, we need better constructs to make sense of conceptual progression that will cut across topics.

There is currently considerable interest in developing defensible progression maps in particular topics, as a way of conceptualizing curriculum sequencing, and also to underpin assessment. We need, however, progression dimensions that occur across topics, to underpin curriculum and assessment planning. Some schemes, based on Piagetian ideas, have been designed to provide a generalized account of quality of response to problems within assessment. The SOLO taxonomy (Biggs & Collis, 1982) is one such scheme. It does not, however, provide guidance on structuring content in a curriculum. There have been schemes developed to describe progression in procedural knowledge. There is interest in using representational demand as the basis for sensible curriculum structuring and some inroads are being made into this (Lehrer & Schauble, 2007). In RILS we found that students grew in their meta-representational knowledge that seemed to transfer across topic boundaries. In framing the primary and secondary school topics on substances and changes to matter there were differences in the sophistication of the representational types and challenges that seemed sensible, but there was no guidance beyond the intuitive, and tradition, that we could draw on. We argue that there is a need to explore systematically the way in which representational competencies progress across the school years.

Representational competence, associated with meta-representational knowledge, underpins conceptual work, transcends topics, and seems promising as a way of
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creatualizing progression generally. Work is needed with teachers in classrooms
to identify these progressions more systematically.

Technologizing the Curriculum

Digital imaging and analysis technologies are becoming increasingly important in
science. In RILS, teachers sometimes worked with digital technologies (animations,
internet searching, digital microscope capture) to good effect. These technologies can
constrain and afford a range of representations, analogies, examples, explanations,
and demonstrations to help make subject matter more accessible to the learner
(Mishra & Koehler, 2006). They will become increasingly important as part of
teachers' representational armory. Sutherland et al. (2004) argued the importance of
young people being able to work with both digital and non-digital tools.

There are numerous examples in the literature of digitally based expert
representations (animations, simulations, data bases, video) being used in learning
sequences, involving students being educated to interpret these. There is a need,
however, to build experience with student use of digital technologies to construct
representations, such as animations / simulations (Linn, 2003), or stop frame video
(Macdonald & Hoban, 2009). The theoretical underpinnings of RILS are well placed
to support this happening in a productive way, with students engaging in discussions
about the relative merits of the different tools. In becoming resourceful learners, they
build awareness of the affordances of the ICT tools they use to construct, work with,
critique and communicate representations. There is a need to further explore the
incorporation of digital technologies into the representation construction pedagogy.

WIDENING THE SCOPE

Socio Scientific Issues and Wider Scientific Literacy Concerns

We have purposely focused on the role of representation in learning foundational
concepts and methods in science in the middle years of schooling because of the
centrality of this focus in mainstream science curricula in many countries. However,
we also recognize the growing emphasis on teaching and learning about socio-scientific
issues (SSIs), where science is understood as one powerful resource, knowledge base,
and repertoire of methods and strategies, among several, for contributing to possible
solutions to real-world problems. SSIs tend to be loosely structured complex topics,
where solutions are multiple and uncertain, and also influenced by ethical, economic
and cultural factors. Researchers in this field, such as Bencze, Sperling and Carter
(2012) and Tomas and Ritchie (2012), recognize the theoretical and practical value
of students constructing re-representations of their SSI understandings and findings,
where these representations can function as both science-based knowledge claims
and evidence of ethical and other understandings of the SSI. Clearly this work entails
major representational challenges in integrating primary and secondary scientific
evidence, claims, and findings with cross-disciplinary evidential claims, leading to new enactments of science literacy. In characterizing and addressing SSIs, teachers and their students face significant major challenges around representational coherence, adequacy, and short-term/long-term fit for purpose. However, we would argue that our approach entailing sequences of representational clarifications/justifications provides instructive leads in (a) enacting pedagogical processes that will develop students’ understanding of the necessarily constructed and partial nature of the knowledge claims that can be made about SSIs, and (b) developing the symbolic and cultural resources needed to generate and judge these claims.

Catering for Diverse Student Cohorts

While our research in RILS was conducted predominantly with middle-class or low socio-economic students, it will be important to investigate whether this approach is applicable to other student groups. We acknowledge that science education researchers from cross-cultural perspectives are seeking to identify and build effective pedagogical bridges between the values, interests, discursive practices and representational resources of different student cohorts and science disciplinary literacy learning (Alvermann, 2004; Ford & Forman, 2006; Gee, 2004; Lee, Luykx, Buxton & Shaver, 2007; Lee & Roth, 2003; Moje, Collazo, Carillo & Marx, 2001; Moje, Peek-Brown, Sutherland, Marx, Blumenfeld & Krajcik, 2004; Wallace, 2004; Waldrip, Timothy & Wilikai, 2007). These researchers assume that this learning is enabled when teachers work with students to (a) negotiate effectively between everyday discourse, culture, and values and those of the science community, (b) develop explicit understanding of the rationale for the norms of science knowledge production and communication, and (c) sustain connections between expression and values in both cultures.

However, as Moje (2007, p. 30) has noted, this “cultural navigation perspective” on science disciplinary learning has tended to take up global, interdisciplinary viewpoints rather than focus on the specifics of textual practices in science, and has often failed to suggest practical ways in which everyday text production can be linked precisely to the literacies of science. On these issues, we suggest that our approach to learning science, in encouraging student representational approximations and negotiation of intended and shared meanings, and multiple opportunities for re-representation, can provide rich and responsive pathways for cross-cultural teaching. Such an approach respects student ideas and range of perspectives grounded in their culture, where a focus on negotiation and clarification of canonical representations can align with the development of cross-cultural understandings.

Integration and Adaptation with Other Subjects

Encouraging results from our approach in both primary and secondary science classrooms has led some teachers to adapt this approach to other subject areas, with claimed positive outcomes. In RILS, we did not investigate this issue. However,
following Lemke’s (1990) view of learning in science as partly about communicative competence in this domain, it is reasonable to suppose that a sustained student focus on representational challenges could be used in other subjects, where students are expected to develop understanding of the domain’s discourse through engaging with its goals and methods. Many successful students are unaware of the discourse (i.e. underlying ways of knowing, thinking and making meaning) of different school subjects because they have learnt this competence through immersion and teacher mimicry. Our representational approach has the potential to facilitate more explicit student knowledge of how the resources of any subject discourse are used to generate and judge its knowledge claims. In RILS we have focused on the affordances of generic and domain-specific representations for learning science, but argue that focusing on both generation and evaluation of representations in other domains can build a classroom community of shared understandings around disciplinary literacies.

Our work in science offers a proof of concept for this domain, but this literacy approach could be adapted to other subjects, such as mathematics or history. In a post-RILS study we have explored the adoption of this approach in Mathematics and English with some encouraging results, but there is a need to explore what subject areas could benefit from this approach. In our representational approach to mathematics, students first prepare a response to a mathematical challenge and share their response and reasons for this response with a group of peers who then develop a common response, with reasons. This approach has been beneficial for improving and clarifying student thinking.

SCALING UP THE APPROACH

In Chapter 8 the question was raised as to the issues involved in scaling up the representation construction pedagogy to system level. These issues are: a) the demands on teacher PCK involved in the approach, especially the need for the teacher to make judgments about the quality and possibilities of student representations, and respond accordingly in individual or classroom settings; b) changes in teacher epistemological beliefs implied by the approach, and c) the time-intensive professional development approach that was used in RILS and the impracticality of extending this to system level. Thus, there is a need for research that further explores approaches to teacher professional learning that could be effectively used to support teachers adopting the approach.

Thus far, we have two indicators of ways forward. The first is the case of Therese, described in Chapter 8, which showed how a receptive teacher can innovate within the approach after even a short period of support. The second is evaluation of a large-scale professional development initiative that was based on representation construction and guided inquiry.

The Switched On Secondary Science Professional Learning (SOSSPL) program entailed two full days of professional learning workshops, which highlighted the representation construction approach. Following the initial two days of the program
the 191 participating teachers were required to implement a small scale classroom-based project that trialled an aspect of representation construction approach in their classroom practice and then return for a third day of professional learning to share their findings. On the basis of their experience in SOSSPL, the vast majority of the teachers perceived the representation construction approach as beneficial to their classroom practices. This was reflected in the surveys and focus group interviews that evaluated the program as well as presentations from the teachers on their classroom-based projects.

Some of the key ideas about representation construction approach were appreciated by the teachers after just the first day where they agreed or strongly agreed to the following Likert statements on the Day 1 evaluation survey.

1. I have developed an understanding of a science concept as a multi-representational entity (97.6% of teachers).

2. I have understood that science involves coordinating and reasoning with multi-modal representations and so generating and negotiating representations is the focus of teaching and learning (93.9% of teachers).

The appreciation for the representation construction approach by the teachers is reflected in the following comments made by individual teachers during focus group interviews that were held following the completion of the SOSSPL program.

But I think for us, it’s reminded us that we shouldn’t be creating them [representations] all the time, that the student needs to create them.

…it does focus attention on students actually puzzling out their own response to key issues that you want to put before them, and it also creates then the conversation that allows you to interact with a student...the engagement between you and the student is more authentic.

I found value in representations as a novel concept of a way of delivering content to students without being a teacher-centred zone. I thought it was a genuine new approach that has a lot of potential.

The evaluation of the SOSSPL program occurred over a short time and did not identify substantive changes to the teachers’ classroom practice. However, the SOSSPL program did provide the seeds for change given the teachers’ perceptions of the value of the representation construction approach and their willingness to embrace the notion of active student representation construction. The benefits of the approach will only be fully realized, however, if teachers move beyond this position.

Currently members of the team are engaged in further research on the representation construction approach, using an action learning team approach to teacher professional development in schools and school networks (Aubusson, Ewing & Hoban, 2009). There is a need for further research exploring the possibility of supporting significant change in classroom practice on a system wide scale.