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Representation construction: a directed inquiry pedagogy for science education

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ABSTRACT

This chapter describes a successful research-developed representation construction approach to teaching and learning that links student learning and engagement with the epistemic practices of science. This approach involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science, rather than focusing on the text-based, definitional versions of concepts. The representation construction approach is based on sequences of representational challenges that involve students constructing representations to actively explore and make claims about phenomena. The key principles of the representation construction approach, considered a form of directed inquiry, are outlined with illustrations from case studies of whole topics in forces and astronomy within several middle-years' science classrooms. This chapter also outlines the manner in which the representation construction approach has been translated into wider scale implementation through a large-scale Professional Development (PD) workshop program. Issues associated with wider scale implementation of the approach are discussed.
INTRODUCTION

Inquiry-based teaching and learning approaches have long been advocated as best practice in science classrooms (Anderson, 2002) but have yet been realized in terms of wide scale implementation (Marshall & Smart, 2013). A significant issue for teachers is a lack of clarity about the meaning of inquiry as it relates to pedagogy and assessment creating the perception that inquiry is difficult to implement in the classroom (Wee, Shepardson, Fast, & Harbor, 2007). According to Bybee (2000), most teachers think that inquiry is time consuming, costs too much, and is too advanced for their students. The research literature describes inquiry in different ways (Anderson, 2002) with most versions separating the experimental methods of science from the knowledge-producing processes. A common interpretation frames inquiry as consisting of both process skills and understandings about the nature of science (Breslyn & McGinnis, 2011). Windschitl (2008, p. 3) argues that “inquiry experiences should foster a deep and well-integrated understanding of important content, as well as the reasoning skills and practices of science – the separation of ‘learning content’ and ‘doing inquiry’ is entirely unnecessary.” This broader perspective of inquiry that aligns content and process within the science classroom provides a better match to the discursive practices by which knowledge is built in science.

Recent Australian Research Council (ARC) funded projects, Representations in Learning Science (RiLS 2007-10), and Creating Representations in Science Pedagogy (CRISP 2012-15), successfully developed and trialed a theoretically sophisticated but practical, inquiry-based approach to teaching and learning, called representation construction, that links student learning and engagement with the epistemic (knowledge production) practices of science (Tytler, Hubber, Prain, & Waldrip, 2013). Inquiry in the science classroom becomes inquiry into ideas and how they are represented, and the selective and partial nature of such representations.

A representation is something that explains some aspect of nature. They can take many different forms or modes (e.g., text, graphs, models, diagrams) and are the means by which we understand and communicate our science understandings. The representation construction approach involves challenging students to generate and negotiate the
representations that constitute the discursive practices of science, rather than focusing on the text-based, definitional versions of concepts. It is based on sequences of representational challenges which involve students constructing representations to actively explore and make claims about phenomena. The approach was implemented in the RiLS and CRISP projects that have successfully demonstrated enhanced outcomes for students, in terms of sustained engagement with ideas, and quality learning, and for teachers’ enhanced pedagogical knowledge (Hubber, 2010, 2013; Hubber, Tytler, & Haslam, 2010).

This chapter describes the principles that underpin the representation construction approach with illustrations from the RiLS and CRISP research and discusses the manner in which the approach has been translated into a major PD program, called Switched on Secondary Science Professional Learning (SOSSPL).

**Background to RiLS, CRISP, and SOSSPL Projects**

The aims of the RiLS project (2007-2010) were to:

a. develop a set of principles for an effective pedagogy, focusing on representational issues, to support the teaching and learning of science;
b. develop practical examples that exemplify these principles;c. identify student learning gains associated with the approach; andd. investigate the challenges teachers face in implementing the approach.

The research team worked collaboratively with six middle-years (5-8) teachers in the development of a 4-6-week sequence (8-12 lessons) on topics known to present learning difficulties in science. Over the duration of the research there were three topics (water, energy, and animals in the schoolyard) taught in the elementary school (years 5/6) and three topics (forces, astronomy and ideas about matter) taught in the secondary school level (years 7/8). Each class contained between 25 and 28 students. A case study methodology (Merriam, 1998) was adopted where, for each topic, the teachers’ practices, student-teacher interactions, student activities and
discussions were monitored using classroom video capture. All lessons were videotaped with two cameras; one camera was focused on the teacher and another camera focused on a group of students. The video data was initially coded using Studiocode software (http://www.studiocodegroup.com/) to identify “quality teaching and learning sequences.” These sequences were subjected to interpretive analysis to identify the teaching and learning principles underpinning them and for evidence in which representations supported reasoning and learning. The teachers were interviewed about their perceptions of the effectiveness of sequences and students were inter-viewed about their understandings of the relationships between representations and knowing. The students’ workbooks provided a continuous record of representational work. A series of workshops were held in which teachers and researchers reflected on and discussed their observations and experiences. Whilst broad perspectives of the principles were adopted in the early years of the project they were refined over time with considerations of the emerging data and the theoretical ideas. During the later stages of the project the teachers employed the refined perspectives of the principles in the development and delivery of the science topics. The RiLS project spawned the CRISP project that began in 2012 and will finish in 2015. It also spawned a Victorian Government Department of Education and Early Childhood Development (DEECD) funded SOSSPL program which ran from 2011 to 2012. The overall objective of the CRISP project is to explore the nature and quality of student learning arising from the representation construction pedagogy by working with groups of teachers as co-researchers using a wider variety of contexts and topics. The aim is identifying key enablers to facilitate quality teacher learning and adaptation of the representation construction pedagogy. A key enabler is the PD given to the CRISP teachers who provide credible narratives generated from the classroom video data supported by the resources used by the RiLS teachers and more importantly, examples of student work. In addition, a workshop setting where the PD facilitator models the pedagogy provides compelling evidence of the efficacy of the application of the approach. Another key enabler is the conceptual focus taken to planning the science topics whereby teachers generate the key ideas and associated representational resources to support student learning of the ideas. The RiLS/CRISP teachers found this enabler a significant move away from their previous traditional textbook focus. A further enabler is the ongoing support generated by members of the school teaching team for each other. The
RiLS/CRISP teachers found their discussions related more to reflecting on and enhancing their teaching practices than they had undertaken previously where collaboration consisted mainly of sharing curriculum resources. The SOSSPL program was in collaboration with the Victorian DEECD and involved over 300 secondary science teachers who participated in 3 days of PD. Following 2 successive days of PD, where the representation construction approach was introduced to the teachers, there followed several weeks in which each teacher applied the approach on a small scale within their normal school practice. A third day of PD followed where the teachers shared their teaching experience in trialing the approach. Data collected in the evaluation of the SOSSPL program consisted of pre- and post-program surveys, focus group interviews, teacher presentations of their classroom-based project and phone interviews of those teachers who agreed to an inter-view (approximately 10%) several weeks following the program.

PRINCIPLES OF A REPRESENTATION CONSTRUCTION PEDAGOGY

The theoretical perspectives that underpin the representation construction pedagogy lie within a socio cultural framework where learning and knowing in the science classroom should be seen as a process of enculturation into the discursive practices of science (Lave & Wenger, 1991). Students need to understand why and how discipline-specific and generic literacies are used to construct and validate scientific knowledge (Moje, 2007). From this perspective understanding and practicing science involves students generating, coordinating and reasoning with multi-modal representations to develop explanations and solve problems (Cox, 1999; Ford & Forman, 2006). These representations include verbal and written language (including topic- and process-specific vocabulary), drawing, three dimensional modeling, mathematical (graphs, tables, equations), and gestural language. In learning these particular literacies of science, students are learning how to invest these representations with appropriate meaning as part of learning how to reason and communicate in this subject (Lemke, 2004). Explicit discussion of the function and form of representations is an important aspect of the teaching and learning that needs to take place in the classroom (Ainsworth, 2006, 2008). The development of students' meta-representational competence (diSessa, 2004) is also important whereby they are able to interpret, construct, translate, and evaluate representations in a scientific manner (Kozma & Russell, 2005). The teacher’s
task in scaffolding conceptual understanding thus becomes, importantly, about representational processes and products. While students have to learn how to interpret and critique authorized scientific representations, a focus on teacher-guided student construction and justification of their own representations can develop conceptual understanding and reasoning capacities in this subject, and enable students to participate in knowledge production methods aligned with scientific practice.

From the theoretical perspectives described above and the teaching and learning practices that emerged from the analysis of the empirical data from the RiLS project, the following set of principles that underpin the representation construction approach to teaching and learning were developed:

1. **Teaching sequences are based on sequences of representational challenges:** Students construct representations to actively explore and make claims about phenomena.
   a. **Clarifying the representational resources underpinning key concepts:** Teachers need to clearly identify big ideas, key concepts and their representations, at the planning stage of a topic in order to guide refinement of representational work.
   b. **Establishing a representational need:** The sequence needs to involve explorations in which students identify the problematic nature of phenomena and the need for explanatory representation, before the introduction of the scientifically accepted forms.
   c. **Coordinating aligning student-generated and canonical representations:** There needs to be interplay between teacher-introduced and student-constructed representations where students are challenged and supported to refine and extend and coordinate their understandings.

2. **Representations are explicitly discussed:** The teacher plays multiple roles, scaffolding the discussion to critique and support student representation construction in a shared classroom process. Students build their metarepresentational competency through these discussions.
   a. **The selective purpose of any representation:** Students need to understand that a number of representations are needed for working with multiple aspects of a concept.
   b. **Group agreement on generative representations:** There needs to be a guided process whereby students critique representations to aim at a resolution.
   c. **Form and function:** There needs to be an explicit focus on
representational function and form, with timely clarification of parts and their purposes.

d. The adequacy of representations: There needs to be ongoing assessment by the teacher and students of the student-constructed representations as well as those representations introduced by the teacher.

3. Meaningful learning: There needs to be provision for strong perceptual/experiential contexts and attention to student engagement and interests through choice of task and encouragement of student agency.

a. Perceptual context: Activity sequences need to have a strong perceptual context (i.e., hands on, experiential) and allow constant two-way mapping between objects and representations.

b. Engagement and agency: Activity sequences need to focus on engaging students in learning that is personally meaningful and challenging, through affording agency and attending to students’ interests, values and aesthetic preferences, and personal histories.

4. Assessment through representations: Formative and summative assessment needs to allow opportunities for students to generate and interpret representations. Students and teachers are involved in a continuous, embedded process of assessing the adequacy of representations, and their coordination, in explanatory accounts.

Illustrations of these principles, described in the sections below, are taken from lesson sequences in forces and astronomy taught in Year 7 and 8 classrooms. In these topics, as well as other topics taught in the RiLS and CRISP projects, importance is placed at the planning stage on the determination of the key concepts that underpin the topic [Principle 1a]. There is a conceptual focus on the design and delivery of the representation construction approach. Examples of key concepts generated for the topics are, “a force is a push or pull of one object (the doer) onto another object (the receiver)” (forces) and, “objects in space spin, or rotate on an axis, and orbit, or revolve around other objects” (astronomy). Such concepts guide the design of representational activities that include representations introduced by the teacher and representational challenges given to students.
**Topic of Forces**

The introduction to the topic of forces focused initially on developing the key concept that force is an “action” word requiring an object called a doer, which applies a push or pull to another object called a receiver. This concept was viewed by the teacher as important for student understanding as it conflicts with the common alternative conception that force is a property of an object (McCloskey, 1983). The lesson began with a whole class brainstorm activity to generate a list of action words the students might use to manipulate a lump of plasticine. The teacher was explicit in repeating the words given by the students and showing by hand gesture their meaning. Very quickly the students were doing the same. Soon a list of action words was generated. From this list the teacher provided a representational challenge whereby the students were to determine if it was possible to sort the action words into the categories of ‘push’ and ‘pull’. Fig. 1 shows two student responses to the challenge, consisting of a tabulation and a Venn diagram. Apart from a class discussion of the similarities and differences in the student classifications of the action words attention was also given to the affordances of tables and Venn diagrams as suitable representational tools in completing the challenge [Principle 2c]. It was agreed by the whole class that Venn diagrams were useful in situations where objects might be classified into multiple categories; the representational need for the use of Venn diagrams was established [Principle 1b]. The teacher led the students to a class view, which they recorded in their journals (see Fig. 1), that “a force is a push or pull of one object (doer) onto another object (the receiver).” The students came to view that forces are actions of push or pull or any of several everyday words they expressed in the brainstorm activity [Principle 1c].

The teacher then gave the students a representational challenge whereby they were to change the shape of a lump of plasticine and then record in their journals the actions that were taken. Students were paired up, one partner took the role of shape maker and the other partner the role of shape copier. The shape copier was given the shape maker’s recording of actions to produce the shape. Both the shape maker and copier then came together to compare and discuss the physical shapes made. Each partner was expected to write a comment in the journal. Fig. 2 shows one student’s journal entry. The shape copier gave a score of 5/5 with the comment “instructions very clear making it easy to make the shape.” The shape maker commented on the shape made by the copier, giving a score of 5/5 with a comment, “Shape was exactly the same. No need to change any- thing” [Principle 2d, 4]. The critique of student-
generated representations was done at the dyad level as well as whole class level in discussions guided by the teacher [Principle 2b]. These discussions led to an exploration of the affordances of the use of diagrams and arrows to show the actions of forces. In this activity and subsequent activities the teacher was coordinating and aligning student-generated representations to the canonical representation of a force, or free-body, diagram [Principle 1c]. In later lessons students were expected to explain everyday actions via a force diagram. One challenge given to the students was to represent the forces involved in opening a screw-top container. They were each given a container and the video-record indicated students moving often between constructing their representation and physically manipulating the container (see Fig. 3 for two examples) [Principles 3a,b].

Fig. 1. Venn Diagram and Tabulation of Action Words to Manipulate a Lump of Plasticine (Year 7).
In the planning stage of the topic there was a recognition that the development of explanations of astronomical behavior such as day/night cycle, sea- sons and phases of the moon required an initial understanding of the key movements of celestial objects given as rotation and revolution. It was also important for students to develop the skill to be able to move easily between the geocentric representations of astronomical phenomena and the space representations in creating explanations of the phenomena [Principle 1a].

![Fig. 2. Year 7 Student's Journal Entries as Part of a Plasticine Shaping Challenge.](image)

In the first lesson the teacher challenged the students to represent their understanding of rotation and revolution through the physical action of their bodies. After demonstrating their understanding through role play the students were to form pairs and given the following representational challenges:

1. The moon always has one side facing the Earth and over the period of a month it undertakes one complete revolution. During this time does it also rotate and, if so, how many times?
2. Is it possible for two celestial objects to revolve about each other?
Fig. 3. Two Year 7 Student Responses to a Challenge to Represent the Forces Involved in Opening a Screw-Top Container.

After several minutes several student pairs came to a solution for one or the other of the challenges through role play. They were using the representational form of a role play as a reasoning tool. The class assessed the representational constructions of student pairs and, through class discussion, came to a view that for challenge 1 the moon undertakes one full rotation each lunar month and, for challenge 2, it was possible for two celestial objects to mutually revolve about each other [Principles 2b, d & 4]. An astronomical application of challenge 2 in terms of the motion of binary star systems was provided by the teacher. Towards the end of most lessons the students were to construct a representation that reflected their learning. Fig. 4 shows what two students constructed at the end of the lesson that involved the role play challenges.

To scaffold the students in moving from a geocentric view of astronomical phenomena to a space view they were given, per pair of students, a small Light Emitting Diode (LED) torch and a mini-globe [Principle 3a]. The teachers reported in interview that the students were often seen manipulating their torches and globes when discussions centered on explanations of phenomena such as day/night cycle, seasons, eclipses and phases of the moon. Such devices provided a physical model accessible to the students in constructing scientific explanations of the astronomical phenomena.

In relation to student learning, comparisons on pre- and post-tests were undertaken between two Year 8 classes and the Kalkan and Kiroglu (2007) study which involved 100 pre-service primary and secondary education teachers who
participated in a semester-length course. Students in each study undertook the same set of multiple choice questions. A measure of comparison of pre- and post-test results is the normalized gain index, $<g>$, the ratio of the actual average student gain to the maximum possible average gain: $<g> = \frac{\text{post} - \text{pre}\%}{(100 - \text{pre}\%)}$ [Zeilik, Schau, & Mattern, 1998]. Gain index values can range from 0 (no gain achieved) to 1 (all possible gain achieved). The mean gain reported by Kalkan and Kiroglu (2007, p. 17) was described as a “respectable 0.3.” In contrast the mean gain for the two Year 8 classes in the RiLS research was significantly higher at 0.63 (Hubber, 2010).

Apart from multiple choice questions the tests included items requiring students to provide an explanation [Principle 4]. Such items provided a substantial space, without lines, for students to respond. Fig. 5 shows several students’ scientifically correct responses to the question, “An astronomer investigating the motion of Europa, which is a moon, or natural satellite, of the planet Jupiter, found that it revolved as well as rotated. Use the space below to clearly explain what each of these motions mean.” The absence of lines for students to provide a response gave the students the opportunity to apply a representational form of their choosing that might be something other than text.

The representational challenges, that are central to the representation
Construction pedagogy, require students to apply higher order thinking processes than recall of the textbook representational forms. Using the language of Bloom’s taxonomy (Anderson & Krathwohl, 2001) the tasks might ask the students to “evaluate” other students’ constructed representations or to ‘create’, from the students’ perspective, new representational forms to solve problems and support claims in explaining scientific phenomena.

TRANSLATION INTO WIDER SCALE IMPLEMENTATION

The successful research-developed representation construction approach has been translated into wider scale implementation through a state-wide SOSSPL program. Crawford (2007) suggests that inquiry-based teaching is complex and sophisticated and so requires significant PD. Loucks-Horsley, Stiles, Mundry, Love, and Hewson (2010) assert that there is widespread consensus that effective PD needs to have student learning at its core and has the following elements:

- It is directly aligned with student learning needs;
- It is intensive, ongoing and connected to practice;
- It focuses on the teaching and learning of specific academic content;
- It is connected to other school initiatives;
- It provides time and opportunities for teachers to collaborate and build strong working relationships and
- It is continuously monitored and evaluated (p. 5).

Voogt et al. (2011, p. 1235) add that PD also needs to “provide examples of concrete classroom applications of the general ideas underlying the change, expose teachers to actual practice rather than providing them with descriptions of practice, and be coherent with teachers’ own professional development (PD) goals and the goals for their student learning.” Such views about effective PD are supported by Capps, Crawford, and Constas (2012) in relation to inquiry-based teaching PD who also argue the importance of improving teachers’ knowledge about inquiry and inquiry-based applications in the classroom. Many of the elements of effective PD described above were incorporated into the SOSSPL program.
Fig. 5. Four Students’ Responses to a Post-Test Question about Rotation and Revolution.
**SOSSPL program**

The purpose of the SOSSPL program was to build teacher capacity to improve student learning outcomes in secondary science with an overarching pedagogy of representation construction. Resources for the PD came from cases studies from several of the RILS project topics that included accounts of the activities that illustrated each of the pedagogical principles supported by examples of students’ constructed representations. Many of the workshop activities placed the teacher participants in the role of the learner and the teaching approach enacted by the facilitator was the representation construction approach. Examples of activities included those presented in this chapter as illustrations of the principles of the representation construction approach. Another example is shown in Fig. 6 which shows a group response to a representational challenge to represent on a small whiteboard the group’s understanding of the concept of temperature. The aim of this challenge was to illustrate to the teachers that a scientific concept consists of a set of interlinked representations and practices. The activities undertaken by the teachers often led to discussions as to the efficacy of adopting such activities in the teachers’ own classrooms. Emphasis was placed on group discussions on the main themes arising from the activities and teachers sharing their practice.

![Fig. 6. A Group of Teachers’ Representation of the Concept of Temperature.](image-url)
They worked together in planning a classroom-based project related to the representation construction approach, which they enacted in the period between the second and third day of the SOSSPL program. On the third day of the program, several weeks later, the teachers shared their experiences in enacting their classroom-based projects.

The teachers saw great benefit in collaborating with other teachers in participating in the activities, discussing the main themes that arose from the activities and sharing ideas and resources. They valued participating in the activities which gave them insights into how they might enact such activities in their own classrooms. Some indicative teacher comments in relation to their perceived benefits in participating in the PD were:

- We have lots of ideas and resources in the workshops that we can apply at school ... there's actual units of work that you can take and follow. It’s wonderful to be introduced to new techniques but this has been documented and you can walk through it if you are not certain. (Focus Group)

- Hands on equipment & follow up because [you] can see from a student’s perspective and actually reflection on one’s own practices. (Survey)

- I really enjoyed collaborating with other teachers & facilitators overall! Sharing ideas and resources during discussion. (Survey)

The participating teachers took ideas from the SOSSPL experience to construct and implement a small classroom-based project between Day 2 and 3 of the overall program. More than 90% of the projects represented innovation from the perspective of the teachers and were based on extension of the ideas focused on in the PD. Comments from the teachers included references to significant reflection based on their own practice using these new ideas:

- Well, I found value in representations as a novel concept of a way of delivering content to students without being a teacher-centre zone. I thought it was a genuine new
approach that has a lot of potential. (Focus Group)

But I think for us, it’s reminded us that we shouldn’t be creating them [representations] all the time that the students need to create them. (Focus Group)

... 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 is more authentic. (Focus Group)

Change in teacher beliefs and attitudes were evident in the increasing value that the teachers attached to the representation construction approach that represented for them, new pedagogical knowledge. Indicative comments included:

I now see better the link between concept development and asking students to represent their ideas. (Focus Group)

I try to be more lateral in my thinking in regards to what we can present to the students and not be textbook-based all the time and present them with tasks that they find stimulating and engaging which are not necessarily straight out of the front of the book. (Focus Group)

My normal practice always incorporated discovery, however I am now more aware of how student forming ideas is more meaningful to them, so I am trying to do this more and more. (Interview)

When I’m setting tests ... I’m giving them a lot more chance to show me what they have learnt in their own way and I’m getting a lot more information too about what their conceptions are. (Interview)
In adopting innovative practices associated with a representation construction approach in their classroom projects the teachers reported:

- the need for flexibility in lesson direction where the students took the lesson in unknown and unexpected directions;
- the approach was catering for a diversity of students;
- a recognized shift in their role when using a representational approach to one of scaffolding learning and not telling them the information;
- a greater insight into the role played by representations in teaching and learning and;
- deeper levels of student learning and greater engagement in science.

Within the project presentations there were many references, some described above, to deeper levels of student learning and greater engagement of students in science through a representation construction approach. This was also evident in interviews. As one might expect, these outcomes for students were compelling for teachers in convincing them of the value of the representation construction approach. Some teacher comments included:

... it gets (students) understanding the key concepts in a really engaging manner in a way I have not seen possible before. (Focus Group)

So yes it is taking us longer [teaching the content] but those key concepts that we are teaching are embedded I believe ... we don’t think it wasn’t happening before - it wasn’t happening before ....We are getting depths of learning. (Focus Group)

For me it’s shown me that I have to hone in on what specifically we need them to learn because we are going for that depth of knowledge now rather than the breadth, so when we plan we may need to cut the curriculum a bit but to get that depth of knowledge I think it’s worth it. (Focus Group)
DISCUSSION AND CONCLUSIONS

The representation construction approach requires students to interpret and construct representations of scientific concepts, claims and processes. By representing some aspect of the world about them, students engage in the processes of knowledge construction of science as well as gaining scientific knowledge. The approach maps well with the creative processes in which scientists explore nature and construct new knowledge. A key implication from a pedagogical perspective is the need to shift practice in teaching science from its traditional focus on the delivery of content that is conceived of as resolved knowledge structures, to the pedagogical practices of a representation approach based on a discursive, more active view of knowledge and learning.

The representation construction approach places demands on the pedagogical skills of the teacher beyond those needed for transmissive approaches. For example, the skills to provide a representation rich environment and opportunities for students to negotiate, integrate, refine and translate across representations. Teachers require good subject content knowledge that entails an understanding of the key representational resources underpinning science topics and an understanding of the role of representation in teaching and learning science. The approach requires of teachers a capability to run open discussions and develop the insights needed to guide the classroom tasks and conceptual negotiation.

The wider scale implementation of the representation construction approach with the 3-day SOSSPL PD was successful, albeit at a superficial level, where the participating teachers found the approach a fruitful and engaging classroom activity. The teachers reported change in their current practices in implementing the representation construction approach. However, the trialing of the approach occurred in a short period of time, ranging from single lessons to multiple lesson sequences. The teachers modified the topic they were teaching at the time and there was no evidence of trialing the approach for a whole topic. In contrast, the teachers in the RILS and CRISP projects planned and adopted the approach for whole topics sequences. There was a representational focus for whole topic sequences from the planning stage to its delivery in the classroom. This was seen as a key enabler to facilitate teacher’s adaptation of the approach found in the CRISP project.

Within the SOSSPL PD the teachers saw great benefit in collaborating with other...
teachers in sharing ideas and resources and, in particular, sharing their experiences in implementing the representation construction approach in their classrooms. In comparison, collaboration among the teachers was at a more sustained level among the RiLS and CRISP teachers. These teachers formed teams in teaching the same topic. They regularly met within their school setting to plan and share their teaching experiences during the teaching of the topic. Discussions held during the teaching sequences allowed the teachers to modify and refine their teaching approach with the teaching period of the topic. It was through this process that the RiLS teachers became increasingly more confident in incorporating the representation construction approach into their practice (Hubber, 2013). Collaboration among the teachers enacting the representational construction approach was found to be another key enabler to facilitate teachers’ adaptation of the approach in the CRISP project.

A further key enabler to facilitate teachers’ adaptation of the representation teaching approach was seen by the CRISP teachers as the curriculum resources developed from the RiLS project that illustrated the approach. The production of web-based PD resources might be a way to introduce new teachers to the approach and to act as a repository to share ideas and resources for practitioners of the approach. The current CRISP project is in the process of developing such a web-based resource (see http://blogs.deakin.edu.au/crisp). This resource may include a classroom video of teachers enacting the representation construction approach. The current CRISP project has gained ethics permissions from teachers and students in the research schools to allow the classroom video-record and student work to be used for teaching purposes in pre- and in-service teaching programs. There are multiple benefits in using video cases in pre-service teacher training and in-service teacher PD in terms of the ability to interrogate and critique the classroom from multiple perspectives (Wang & Hartley, 2003). The composition of the website and the manner in which it can support a collaborative PD environment represents a useful direction for further research.

In relation to the literature on effective PD (Loucks-Horsley et al., 2010) the SOSSPL program directly aligned with student learning needs; was connected to practice; focused on the teaching and learning of specific academic content and provided time and opportunities to collaborate. However, PD in relation to implementing an inquiry-based teaching approach such as representation construction not only needs to provide resources that illustrate the approach it
also needs to emphasize a team-based focus for teachers at the school level in planning and teaching whole topics sequences.

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