Teacher change in exploring representational approaches to learning science

Peter Hubber, Deakin University, Australia
Email Contact: phubber@deakin.edu.au

Abstract
The researchers worked with two experienced teachers in planning a series of three teaching sequences in the topics of force, substances and astronomy using a teaching approach that highlight representational issues and options in helping students explore and develop key conceptual understandings. Classroom sequences involving the two teachers were videotaped using a combined focus on the teacher and groups of students. Video analysis software was used to capture the variety of representations used, and sequences of representational negotiation. The teachers reported substantial shifts in their classroom practices, and in the quality of classroom discussions, arising from adopting a representational focus. From an epistemological perspective the teachers came to terms with the culturally produced nature of representations of force, substance and astronomy and their flexibility and power as tools for reasoning and communication, as opposed to their previous assumption that this was given knowledge to be learnt as an end point. From a pedagogical perspective the representational approach was acknowledged to place much greater agency in the hands of students, and this brought a need to learn to run longer and more structured discussions around conceptual problems.

Introduction
The difficulties encountered by individuals in learning science point to the necessity for a very strong emphasis of the role of representations in learning. There is a need for learners to use their own representational, cultural and cognitive resources to engage with the subject-specific representational practices of science (Gee, 2004; Klein, 2006). Researchers who have undertaken classroom studies whereby students have constructed and used their own representations have pointed to several principles in the planning, execution and assessment of student learning (diSessa, 2004; Greeno & Hall, 1997). A key principle is that teachers need to identify big ideas, key concepts, of the topic at the planning stage in order to guide refinement of representational work. These researchers also point out the need for students to engage with multiple representations in different modes that are both teacher and student generated. A representation can only partially explain a particular phenomenon or process and has both positive and negative attributes to the target that it represents. The issue of the partial nature of representations needs to be a component of classroom practice (Greeno & Hall, 1997) in terms of students critiquing representations for their limitations and affordances and explicitly linking multiple representations to construct a fuller understanding of the phenomenon or process under study. The classroom practice should also provide opportunities for students to manipulate representations as reasoning tools (Cox, 1999) in constructing the scientifically acceptable ideas and communicating them.

Research Methods and Question
The researchers worked closely with two experienced teachers, Lyn and Sally¹, to plan teaching sequences that highlight representational issues in helping students explore and develop key conceptual understandings. This occurred initially over a 2 year period with sequences in the topics of forces, substances and astronomy. The planning sought to develop a model of classroom practice that foregrounds representational negotiation as a basis for conceptual growth. A forces topic was taught to Year 7 students (12 year-old) and the second and third topics on substances and astronomy were taught to the same students the following year. The lesson allocation to each topic sequence is given in Table 1; lessons lasted 45 or 90 minutes.

¹ Pseudonyms have been given to teachers in this study. Where reference has been made to names of students pseudonyms have also been used.
Table 1 Lesson allocation to each topic sequence

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Number of lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 2007</td>
<td>Forces</td>
<td>12</td>
</tr>
<tr>
<td>May 2008</td>
<td>Substance</td>
<td>14</td>
</tr>
<tr>
<td>Aug. 2008</td>
<td>Astronomy</td>
<td>12</td>
</tr>
</tbody>
</table>

Research Question
The research question was: how did teacher’s practice and beliefs change and develop over time in response to an explicit representational focus in teaching science?

Data Collection
Data collected included: (1) video recordings of most classroom sessions and of student interviews; (2) student workbooks; (3) pre- and post-tests (for substances and astronomy topics only); (4) transcripts of tape recordings of teacher and (5) student interviews and researchers’ field notes.

The videotaped lessons were coded using ‘studiocode’ software which has been designed for this type of analysis, to allow quick reference to representational events and instances of classroom negotiation of representations. The analysis reported here involved triangulation between video data, transcripts of student and teacher interviews, student work, pre- and post-tests and researcher field notes. Data reported in this paper include interpretive perspectives and examples from various contexts and settings.

Approach to planning the topic sequences
In coming into this study Lyn and Sally were experienced practitioners who were capable of innovative use of strategies based on the development of students’ representations. Both teachers were biology trained and specialised in teaching this subject at senior levels of schooling but taught general science at junior levels. From this perspective the topics of forces, substances and astronomy were outside their main area of expertise.

The initial approach to planning the representationally focused topic sequence was similar for each of the three topics. The research team collaborated with the teachers in identifying big ideas or key concepts of the topic in addition to the students’ alternative conceptions reported in the literature. The initial lessons in each teaching sequence focused on exploration of students’ prior views, generation of students’ representations, and introduction of the scientific conventions that underpinned each topic. Each teacher followed a similar sequence of activities, but in fact each was different in the way they introduced ideas, led discussions, and achieved some form of closure. To provide some insight into the specific approaches undertaken by the teachers the following cases of Lyn where she introduced concepts of force in the first of the three topics taught is given.

Case of Lyn – introducing forces
What is described here is an outline of the first few lessons of the forces teaching sequence as taught by Lyn. The lessons are described as a series of sequenced stages.

Sequence stage 1
Lyn began the sequence by developing in students an understanding of the term ‘force’, assisting them to construct meaning for force through their everyday language. She did this by initially eliciting from the students’ everyday action words they used, given the task of changing the shape of a lump of plasticine. A brainstormed list of words was quickly constructed and displayed on the board, including stretch, carve, twist, roll, squeeze, mould and poke. Lyn used gestures to re-represent the words as they were given by the students. Many of the students also provided a gesture explicating their uttered word. This was a noticeable feature of the teachers’ and students’ communication during this topic, that gestures became an important part of describing and validating what was being represented in words or diagrams. Gestures were used to indicate pushes, pulls or lifting forces, to mime the size of forces, and to indicate the force’s direction and points of application.

From the initial brainstorm listing Lyn re-represented the list into a tabular form after discussing with the students whether each of the elicited words could be placed into a column labelled ‘push’ or a
column labelled ‘pull’. She then introduced the scientific meaning of a force as a ‘push or pull of one object onto another’.

**Sequence stage 2**

Lyn explored with the students various ways in which an everyday action or series of actions involving forces could be represented in a two dimensional form on paper. The students were given the one minute task of changing the shape of a handful sized lump of plasticine, and following this task, they were to represent their actions in changing the shape of the plasticine in paper form. The different representations constructed by the students, some of which are shown in Figure 1, were shared, discussed and evaluated within a whole class discussion.

*Student 1*  
*Student 2*

![Fig. 1 Student representations of manipulating plasticine](image)

One representation which had a series of figures with sequenced annotation (Figure 2 Image A) was unanimously accepted as providing clarity of explanation of the actions that were undertaken. This is illustrated by the following commentary extracted from a video segment:

Lyn: *Which one of these representations worked well in explaining what was done?*  
Student 1: *John’s (image A) because it should you exactly what to do. Mine could have ended up anything.*  
Student 2: *It (image A) was more visual, you can actually see it is easier to actually see what you did. With the other ones you could make it in different ways.*

![Image A](image) ![Image B](image)

*Fig. 2 Reproduction of video images of John’s representations*

**Sequence stage 3**

Lyn introduced force diagrams, which use the scientific convention of representing forces as arrows. She did this by discussing with the students the benefits in drawing arrows, to represent pushes and pulls, to John’s drawings to enhance the explanations (Figure 2 Image B). The students were then given the task of re-representing their explanations of changing the shape of the plasticine in pictorial form using arrows (Figure 3).
The completion of this task produced different meanings of the use of arrows, which Lyn discussed with her students. Several issues were raised and discussed, and which included:

- Distinguishing between the arrow representation as a force or as a direction of motion;
- Distinguishing between different types of arrows, such as curved or straight, thick or thin, many or few.

**Sequence stage 4**

Lyn introduced the scientific convention of representing forces as straight arrows, when the base of the arrow is the application point of the force, the length of the arrow gives an indication of the strength of the force, and the arrow head indicates the direction of the force. The students were then encouraged to apply this convention to various everyday situations where forces are applied. Two examples of these include: (i) students were each given an empty soft-drink capped bottle and asked to represent the forces needed to twist off the bottle cap (Figure 4 Image A), (ii) students were given a piece of plasticine and asked to stretch the it with a gentle stretch and a rough stretch. They were then asked to use the arrow convention to represent a gentle, and a rough stretch on the plasticine (Figure 4 Image B).

**Findings and conclusions**

In this study the teachers confirmed the efficacy of a representational focus in teaching and learning the key science concepts in the topics of force, substances and astronomy. The teachers reported substantial shifts in their classroom practices and beliefs in response to an explicit representational focus in teaching science. From a pedagogical perspective this approach was acknowledged to place much greater agency in the hands of students, and this brought a need to learn to run longer and more structured discussions around conceptual problems. Both teachers were very positive about this change in their teaching, and the video record showed increased confidence in guiding discussion over the three topics that were taught.
The teachers took more of a conceptual focus to topic planning moving away from a practice of covering curriculum content contained in the students’ textbooks. In doing so the teachers sacrificed content coverage for the greater depth offered by this approach, and were unanimous that this change paid dividends in student learning.

Lyn: Before we crammed it all in and didn’t know what to cut out...we were so pleased to actually pause, particularly in that forces unit, which was so superficial and done so badly [in past years] according to the textbook that we were using. We were so pleased to go into depth. And it was so lovely to be able to develop ideas with the kids.

The representational focus meant that the content to be covered was conceived of as an interconnected set of ideas linked by representations. This interconnectedness and a greater involvement of students in classroom interactions leads to a greater flexibility is required in terms of what content is to be covered each lesson. For the teachers this meant a change in their topic planning practices where they believe that planning for topics now involves preparing for possible changes in direction which result from current classroom interactions rather than following a fixed planning schedule which was their previous practice.

Sally: ...you plan your lesson with a lot of possibilities. You think about okay what if the students ask me this question, what kind of activities can I have and I’m a little bit more prepared ...now way back, if I did this last year, I would’ve prepared a whole 5-week lesson and I’d be teaching it lesson, by lesson, by lesson. So that’s the progression.

From an epistemological perspective the teachers came to terms with the culturally produced nature of representations in the topics of force, substance and astronomy and their flexibility and power as tools for analysis and communication, as opposed to their previous assumption that this was given knowledge to be learnt as an end point. These realisations became empowering as they learnt to use representational challenges to drive classroom discussions and to achieve greater understandings themselves to interpret force and motion situations, apply particle ideas to explain properties of substances and interpret astronomical behaviour in terms of the interplay between simple dynamic systems of celestial objects. This meant that over the three topics the teachers enhanced their content knowledge and pedagogical content knowledge which was driven by undertaking the representational focus. The following quotes gives insight into the manner in which the teachers now perceived the role of representations in understanding science:

Lyn: Sometimes the representation will help us to get to that knowledge. So it is a continuous feed-back; as Sally said, if we try to understand the concepts we have to go to various types of representations...Representations help us get the knowledge, we use the knowledge to help to build our representations.

Researcher: So is it two-way?

Lyn: A circle. The representations helped our knowledge and our knowledge helped our representations and the more representations helped our knowledge and the more knowledge helped our representations. So it was more a continuous feedback working.

The teachers reported on the use of more modes of representation and over the period of the three topic sequence the teachers gained in confidence in setting representational challenges that led to significant representational activity.

Lyn: I always used representations but particularly stronger for instructions and then I would just use visual representations...and now I use many different forms.

The representational focus to the teaching of the three topics led the teachers to change in the manner in which they viewed the diagnostic, formative and summative aspects of assessment. In moving to a practice of employing diagnostic tests the teachers saw the knowledge gained from the test results as beneficial in terms of targeting the teaching in resolving misconceptions and for the students to be made aware of their own thinking as an important part of the teaching sequence. The teachers saw that the resolution to resolving the students’ naïve conceptions as very much a representational issue in terms of the use of representational challenges to drive classroom discussions. The students were given many opportunities to interpret and generate representations which gave the teachers a good sense of the students’ learning from a formative and summative perspective. By the third topic on
astronomy the teachers found that formative and summative assessment could be enhanced though providing spaces in the students’ workbooks and tests to encourage the generation of representations. The connection of assessment and representations is summed up in the following quote by Lyn:

Lyn: ...what you’re seeing with representation is that you’re seeing what’s in their brain, not what they’re regurgitating.

The two teachers were strongly of the opinion that this representational focus had significantly impacted on student learning and engagement. Their perceptions of improved learning and engagement were central to their acceptance of change to their practices and beliefs.

Sally: It’s good to give them a representation, but it’s more powerful when they re-represent it...it helps in their reasoning.

**Implications**

A key implication of the study is the need to shift practice in teaching science from its current focus on the delivery of content that is conceived of as resolved knowledge structures, to the pedagogical practices of this representation approach based on a discursive, more active view of knowledge and learning. This will require changes in conceptions of the role of the teacher in the science classroom, and changes in how knowledge and learning are thought of in science. To make this change, teachers need to:

- understand the role of representation in learning science, implying both a pedagogical and an epistemological shift;
- provide a representation rich environment and opportunities for students to negotiate, integrate, refine and translate across representations;
- make explicit to students the role of representation in learning science; and
- conceptualize learning in science in terms of students’ induction into the representational conventions and practices of science and their capacity to coordinate these.

Given current concerns about the engagement of students in meaningful science learning, and the relatively limited success of pedagogical approaches based on cognitive views of learning, I would argue that this is an agenda that needs to be vigorously pursued both in research and policy.

**References**


