How does that work? Developing pedagogical content knowledge from subject knowledge

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The importance of explanations in teaching

• Good teachers are good at explaining (Wilson & Mant, 2011).
• Little science education research into teacher explanations (Geelan, 2012).
• Not looking at lectures/teacher-talk.
• Explanations or ‘stories’ to explain an event (Ogborn et al., 1996), to be developed into common knowledge through ‘discourse and joint action’ (Edwards & Mercer, 1987).
The importance of explanations in teaching

• Explanatory stories crucial to learning (Millar & Osborne, 1998).

• Beginning science teachers need to learn how to introduce and develop the scientific story.

• Study presents one such approach.

• Also makes theoretical contribution about relationship of PCK to SK.
Developing pre-service teachers’ subject knowledge

- SK held to be key indicator of quality of science teaching (Royal Society, 2011).

- Can encourage graduates with higher qualifications e.g. new bursary scheme.

- Develop SK during ITE (Lock, Salt & Soares, 2011)
  - Interactive workshops
  - Self-assessments
  - Diagnostic questions

- Process: science school science (Kind & Taber, 2005; Kind, 2009).

- International concern about recruitment and retention of science teachers (e.g. OECD, 2005; Rhoton & Bowers, 2003).
PCK in science education

- “special amalgam of content and pedagogy that is uniquely the province of teachers, their own form of professional understanding” (Shulman, 1987).

- Various definitions and conceptualisations of PCK (Gess-Newsome, 1999; Nilsson, 2008).

- Teachers need support to identify and articulate components of PCK (Mulhall, Berry & Loughran, 2003; Loughran, Mulhall & Berry, 2004).
PCK in science education

• Science teachers need to acquire ability to develop effective explanations of key scientific concepts in the classroom – part of PCK.

• Little is understood of explanatory frameworks teachers draw upon (Geelan, 2012).

• Research project characterising effective science explanations from teachers’ and pupils’ perspectives.

• ‘Baseline’ investigation.
The value of writing narrative explanations

• Previous research into writing narrative explanations of scientific phenomena
  – Newton’s cradle by researchers and teachers (Edington & Barufaldi, 1995)
  – Balloons by primary teachers (Johnston & Ahtee, 2006)
  – Mechanics by undergraduates (Touger et al., 1995)
  – Primary pupils (Carvalho & Paulo, 2004)

• Useful for exploring science subject knowledge
• Can help to develop subject knowledge
Methodology

Aimed to examine the explanations held by preservice science teachers which they then drew on to explain scientific phenomena in the classroom. Initial focus was on outcomes, but soon became apparent that process of writing narrative explanations was significant.
Methodology

• Series of workshops: Particles, Forces, Electricity and Energy
  – Develop subject knowledge
  – Identify common misconceptions
  – Variety of teaching and learning strategies

• Key demonstration introduced and discussed
  – Not always fully understood
  – Not their own explanations
  – Not the difference between describing and explaining

• ‘Rather than attempt to train all students to teach in a particular way, we aim to build on your existing strengths – as good scientists, and as mature, autonomous, motivated personalities – to help you teach in the way most suited to you and your school students.’
Methodology

Task – write explanation of key demonstration, which was then marked.

Sample characteristics
• 49 PGCE students
  • 18 physicists, 17 chemists, 14 biologists
• Gender: 29F : 20M
• Age range: 22-51 years
Four demonstrations

Standard part of a science teacher’s repertoire

• Egg and conical flask
• Rocket balloons
• Burning pencil
• Melting ice
Evaluating the written tasks

• End of term evaluation form

<table>
<thead>
<tr>
<th>The 4 explanations tasks</th>
<th>Yes</th>
<th>No</th>
<th>Missing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did these tasks help you to develop your subject knowledge? Please explain your answer.</td>
<td>38</td>
<td>7</td>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td>Did these tasks help you to think about how to explain concepts to students? Please explain your answer.</td>
<td>41</td>
<td>3</td>
<td>5</td>
<td>49</td>
</tr>
<tr>
<td>Did you find the written feedback useful? Please explain your answer.</td>
<td>41</td>
<td>4</td>
<td>4</td>
<td>49</td>
</tr>
</tbody>
</table>
Evaluating the written tasks

- Majority offered justification for their responses
- Used to devise a semi-structured interview schedule
- Four focus groups (2-4 in each)
  - Biologists
  - Chemists
  - Biologists and physicists
  - Biologists and chemists
Did completing the written tasks aid subject knowledge development?

Questionnaires: yes (38/49)

– Highlighted areas they needed to revise (9)
– Helped to clarify concepts and deal with their own misconceptions (5)
– Taught them new concepts (4)
Did completing the written tasks aid subject knowledge development?

Interviews: yes!

- ‘It was really useful for building your curriculum knowledge across the board.’

- ‘I just knew as a fact that metal conducts better than wood, but I realised that I’d either forgotten or never really knew why.

- ‘I’ve been away from science for a while, and actually just sort of trying to work things out from first principles again was really helpful for me’
Did completing the written tasks aid subject knowledge development?

• Opportunity to learn from peers
  – ‘I found myself having to ask the physicists about things and checking things with the chemists’

• Think about phenomena in more depth
  – ‘we’ve all seen a rocket balloon go before and I think quite a few of us had seen the egg, but never really sat down and gone ‘How does that do that?’

• Realise level of assumed knowledge
  – ‘you sort of know a lot of stuff that you think everybody else knows, but actually they don’t really know that’
  – ‘it becomes sort of internalised knowledge that you don’t need to think about, but then it’s really difficult to explain to someone else’
Did completing the written tasks aid subject knowledge development?

The process of writing narrative explanations of four simple phenomena enabled the pre-service teachers to develop their own subject knowledge, where needed, and to translate their ‘academic science’ into ‘school science’ (Kind, 2009).
Did the written tasks help the pre-service teachers to develop their PCK?

- Learning to explain demonstrations
- Giving feedback to students
- Learning science from students’ perspectives
- Professional development
- Evidence of impact on their professional practice
Learning to explain demonstrations

- Introduction to demonstrations
- How to plan and prepare discussion – enabling students to make meaning (Mortimer & Scott, 2003)
- Questionnaires: yes (41/49)
  - Need for clear, logical argument from basics (13)
  - Think about explanations in new way (5)
  - Careful use of language (4)
  - Students’ perspective of learning (4)
Learning to explain demonstrations

Interviews: yes!

• Encouraged them to use diagrams and step-by-step approach

  – ‘what do I need to explain first before I can explain what happened there?’

  – ‘you’ve got to make sure that you know what you’re explaining and keep using the same terms’

  – ‘when I came to doing teacher demos, it helped me think about how am I going to set this up, how am I going to make them think about what I want them to think about but not necessarily say exactly what’s going on’
Learning to explain demonstrations

• Opportunities to think about the demonstrations in detail, ensuring they fully understood what was occurring and why.

• Appreciate the complexity of these apparently simple phenomena and the importance of using scientific language carefully (Wellington & Osborne, 2001; Wellington & Ireson, 2008; Evagorou & Osborne, 2010).

• Able to generalise these principles and apply them to other demonstrations, valuing the confidence that they gained from feeling well prepared.
Giving feedback to students

• Modelling good pedagogy: questioned and expected to develop their own thoughts, fostered by opportunities to discuss with peers (Mortimer & Scott, 2003)

• Marking highlighted importance of written feedback.

• Individual guidance for improvement.
Giving feedback to students

Questionnaires: yes (41/49)

- Helped improve their explanations (11)
- Improved their subject knowledge (5)
- Useful (8)
Giving feedback to students

• Interviews: yes!
  – ‘it was very focussed on which bits you’d done well, which bits you need to think about more’
  – it was ‘very important’ and made the whole exercise ‘meaningful’
  – ‘came back to read it and thought ‘Oh, you know I haven’t really included that in my explanation’”
  – ‘training them to write explanations of their own thoughts. It’s what teaching’s all about, getting the thoughts onto the paper’
Giving feedback to students

Individual written feedback greatly valued by the pre-service teachers and was an important part of the process.
Learning science from students’ perspectives

Questionnaires

• Did not help their subject knowledge (7)
  – Insufficient time (4)
  – Hard and confusing (3)
  – Already knew it (2)

• Did not help with explaining
  – Tasks hard (3), insufficient time (2), task unclear (1)

• Feedback not helpful
  – Model answer (4) and a mark (1) wanted
  – Demoralising (2) and too fussy (2)
Learning science from students’ perspectives

Interviewees unsympathetic:

• ‘that’s what we do to the kids all the time, and that’s the challenge for them and you learn things from the challenge. You can’t just leave us here all afternoon to write, it just would be ridiculous’

• More time would have allowed them to ‘go off on a tangent and start thinking about it, getting more and more flustered and more and more confused’

• ‘it made me appreciate how students can struggle with concepts in the classroom because I was struggling with it’
Learning science from students’ perspectives

• Negative comments reflected ‘comfort levels’
  – ‘it’s not any more demoralising than any other session that we’ve had this year’
  – some people ‘are just generally demoralised’
  – ‘I’m one of those people that doesn’t want to write something down until I think I’ve got it right’
  – Time allowed was longer than thinking time in classroom after student has asked a question.
Learning science from students’ perspectives

Theses insights into learners’ perspectives were useful to them when working with students in school.
Professional development

A more structured task

— ‘wouldn’t have highlighted to me exactly where my misconceptions lay or where my lack of communication was’

— would have restricted the way they developed their own subject and pedagogic knowledge through the tasks
Professional development

Interviewees’ thoughts on the written feedback

– ‘encouraging’
– ‘you were stretching us rather than being picky, it felt like being stretched’
– this was what good teaching was about – ‘you could always improve on something’
Interviewees’ thoughts on model answers

– Could ‘google’ straight after workshops

– ‘a model explanation is really only in your words. And actually what we need to do is to develop the skills to put in our words. So actually it wouldn’t really have helped really’

– A useful option for those who felt their own explanations to be inadequate
Professional development

Interviewees’ thoughts on marks

- Superfluous
- Feed unhealthy competitiveness
- Difficult to devise fair mark scheme
- Wouldn’t ‘help you be a teacher’
Professional development

Interviewees able to articulate how process had enabled them to develop their professional practice in an autonomous way.
Evidence of impact on practice

In their classrooms

— Used same questioning approach in marking
— ‘I set them as homework to write an explanation’
— ‘they could tell me what was going to happen, but when it happened they couldn’t believe it and they were really excited’
— ‘each demonstration is quite exciting to watch but also because you haven’t necessarily been taught it, they can come up with a range of explanations and then it’s something to focus a lesson on’
Evidence of impact on practice

• Made consideration of PCK explicit
  – ‘really thinking about exactly how you’re doing your explanation and keeping it as simple but as clear as possible’

• Importance of language and diagrams
  – ‘I taught a lesson where I was thinking ... because I’d gone through that exercise ... about specific terms and careful use of language’
  – ‘Because some things you really can’t convey as well with words as you can with pictures’
Evidence of impact on practice

The process of writing an explanation of a particular phenomenon for assessment helps to identify any misconceptions still held, in order to develop one’s subject knowledge.

More importantly, the process of writing an explanation helps to organise one’s knowledge in a way which simply answering questions does not.
Coherent internal accounts

The identification of an explicit step for science teachers to take when transforming their subject knowledge into PCK

- the development of a coherent internal account (CIA)

A CIA is the ‘story’ which is

- held by the science teacher which explains the phenomenon in question

- the understanding they wish to share with their students for them to take away
Coherent internal accounts

- Process had revealed need to
  - ‘organise your thoughts and think what do you need to discuss first in order for the pupils to get to the point where they have that understanding’
  - ‘if you write it down yourself you might realise that you can’t explain it .... unless you try and put it into words either on paper or spoken then you might not realise that what’s in your head is not necessarily that ordered’
  - ‘there is a difference between being able to quote a definition and being able to understand what the definition means’
Coherent internal accounts

- Various models of different forms of teachers’ professional knowledge (Kind, 2009)
- CIAs provide a way of making transformation between SK and PCK explicit to science teachers
Coherent internal accounts

• Different to teachers showing they know and understand a concept e.g. by answering a set of diagnostic questions

• Having a CIA is being able to use this knowledge to explain a particular phenomenon

• Next step is using their PCK to teach it to others
Coherent internal accounts

• Suggest experienced science teachers have CIAs
• Pre-service teachers need to develop them – how?
• Process described is one approach
  – Enabled them to organise their own thoughts and understandings in preparation for doing demonstrations with students in school
  – Important to be done at an individual level
  – Inherently valuable for pedagogical development
  – Substantial marking load and criticisms of process
Subsequent adaptations

• Process retained as part of PGCE course
• Longer discussion in task introduction
• Verbal ‘model answer’ given
• Still issue of marking
Conclusions

- SK – PCK relationship complex (Kind, 2009)
- Shortage of research into experienced science teachers’ explanations (Geelan, 2012)
- Coherent internal accounts are crucial step in process of developing PCK from SK
Conclusions

• Pre-service teacher education should enable development of coherent internal accounts
  – Realisation of need for CIAs
  – carefully thought through for their use of language, models and analogies
  – aim to improve scientific understanding, not perpetuate misconceptions
  – good CIAs explain phenomena, drawing on key scientific concepts and relating them to others
  – Written nature makes process explicit and allows formative feedback
Developing pedagogical content knowledge from subject knowledge through coherent internal accounts

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Examples of narrative explanations written about the burning pencil demonstration.

- Two power packs connected in series give the circuit a high potential difference. The circuit is completed, causing current to flow. The graphite core in the pencil is a semi-conductor and has a high resistance. This means that the electrons collide with the carbon atoms of the graphite more frequently. This results in a large number of the electrons passing their energy onto the graphite via vibrations. The large energetic vibrations transfer energy as heat to the wood. The combination of heat (vibration energy of the particles), fuel (wood) and oxygen cause the wood of the pencil to catch alight and burn.

- The pencil is sharpened at both ends and crocodile clips used to connect the graphite into the series circuit with two power packs. Graphite is a semi-conductor, so it conducts electric current, but not very well: the rate of flow of electrons is the electric current. When the switch is turned on, the electrons (current) start to flow. The power packs in series give a large amount of energy to each unit of charge flowing through (24V=24 joules per coulomb).

- Since graphite is a poor conductor, it presents resistance to electron flow through it. The electrons collide with the atoms of carbon as they flow through. These collisions transfer energy from the electrons to the carbon atoms, which start to vibrate more, which results in an increase in temperature. More and more electron collisions produce more and more heat in the carbon/graphite. Eventually, the temperature gets high enough for the wooden pencil casing to spontaneously combust.

- The pencil is acting as a resistor with the graphite of the pencil completing the circuit. Electrons are given energy by the battery. They flow round the circuit in a stream, forming a current driven by the ‘push’ from the battery – its potential difference. The electrons have to give up their energy to get through the pencil since the graphite has a high resistance in comparison to the wires. This is why we need 24V, we need enough to get enough electrons going through. This energy transforms into heat. Eventually the graphite gets hot enough to make the wood burn.