

'CoRes and PaP-eRs as a strategy for helping beginning primary teachers develop their pedagogical content knowledge

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ABSTRACT (CoRes y PaP-eRs como una estrategia para ayudar a los maestros de primaria principiantes a desarrollar su conocimiento didáctico del contenido)

While it is widely accepted that beginning teachers have little PCK, this paper attempts to explore whether two instruments, CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires), might offer a means for articulating and portraying aspects of a beginning primary science teacher's developing PCK and how this might assist in developing his PCK. This has implications for all teachers of science including those of chemistry. Over a two year longitudinal study, a beginning primary science teacher developed his own CoRe and PaP-eR, accompanied by an analysis of his thinking behind his practice. On analyses, the study concluded that CoRes and PaP-eRs can portray explicit instances of PCK for a beginning science teacher but more importantly they help to highlight, build and scaffold knowledge of teaching and learning about science in new ways that extends beyond normal beginning teacher thinking. Therefore CoRes and PaP-eRs might be of potential interest to beginning science teachers in all disciplines (including chemistry).

KEYWORDS: Pedagogical Content Knowledge, teacher development, content representations (CoRes), pedagogical and professional-experience repertoires (PaP-eRs), beginning teacher development

Resumen

Mientras es ampliamente aceptado que los profesores principiantes tienen un reducido CPC (Conocimiento Pedagógico del Contenido), este artículo intenta explorar si dos instrumentos, CoRe (Representación del Contenido) y PaP-eRs (Repertorios de experiencia Pedagógica y Profesional) pueden ofrecer medios para articular y representar aspectos del desarrollo del CPC de profesores principiantes de ciencia en la primaria. Esto tiene implicaciones para todos los profesores de ciencia, incluidos aquellos de química. Mediante un estudio longitudinal de dos años, un profesor novato de primaria desarrolló su propio CoRe y PaP-eR, acompañado de un análisis de sus razonamientos detrás de su práctica. Del análisis, este estudio concluyó que CoRes y PaP-eRs sí pueden representar instancias explícitas del CPC para un profesor principiante de ciencia en primaria, pero más importante que eso, es que ayudan a destacar, construir y dar andamiaje al conocimiento de enseñanza y aprendizaje de la ciencia de nuevas formas que se extienden más allá del razonamiento de un profesor novicio. Por lo tanto, CoRes y PaP-eRs pueden resultar de interés potencial a los profesores principiantes de todas las disciplinas científicas (incluida la química).

Palabras clave: Conocimiento Pedagógico del Contenido, desarrollo del profesor, Representación del Contenido (CoRe), Repertorios de experiencia Pedagógica y Profesional (PaP-eRs), desarrollo de profesor principiante

Introduction

Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) have been extensively reported in science education literature as significant instruments which are claimed to be effective in articulating

and portraying aspects of the tacit, intrinsic and individualized component of teachers' professional knowledge that has come to be known as pedagogical content knowledge (PCK) (*cf.* Kind, 2009; Hume and Berry, 2011; Loughran, 2012). In chemistry education, PCK has been researched with practising teachers (*cf.* van Driel, Verloop, and de Vos, 1998; Bucat, 2004), and much more intensely with pre-service teachers (*cf.* Hume and Berry, 2011, Nilsson and Loughran, 2012, Rollnick, *et al.*, 2008). This research highlights the need for further studies into PCK and how it

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develops in teachers as they progress through their career. It has important implications for how chemistry is taught and learned.

Shulman (1986) offered PCK as a distinct domain of teachers' knowledge because it aimed to bring to the surface the understanding, reasoning, and underpinnings that a teacher develops in learning how to link content and pedagogy in meaningful ways in practice. In the absence of PCK (i. e., if the amalgam does not exist so that content and pedagogy are not linked) then it could well be that the teacher just happens to have a good activity. PCK, therefore, is the individual and unique knowledge a teacher possesses that marries knowledge of content and knowledge of pedagogy together in a way which enhances student learning (Loughran, *et al.*, 2012). It then becomes clear that PCK develops with teaching experience — that experience usually includes different pedagogical approaches for teaching particular content to different student groups over time. The act of teaching then adds a richness in building the teacher's PCK. On the converse, it has been commonly suggested that beginning teachers, therefore, have very little PCK (Baxter and Lederman, 1999; Gess-Newsome, 1999; Grossman, 1990; Magnusson, Krajcik, and Borko, 1999; van Driel, *et al.*, 1998). It would, therefore, be interesting to see whether CoRes and PaP-eRs are an appropriate framework that, in the first instance, might represent the (limited) PCK of beginning science teachers, and in the second instance, be a useful device in meaningfully supporting and scaffolding their developing PCK once they begin teaching.

PCK, CoRes and PaP-eRs

Science teachers' PCK is often tacit and difficult to articulate, capture and portray because of its very personal construction (Gess-Newsome, 1999; Korthagen and Kessels, 1999; Loughran, *et al.*, 2012). Loughran and colleagues developed a Resource Folio — a framework which they contended could capture and portray these personal and idiosyncratic examples of PCK (*cf.* Loughran, *et al.*, 2012; Loughran, Mulhall, and Berry, 2004). A Resource Folio consisted of a Content Representation (CoRe) and any number of Pedagogical and Professional-experience Repertoires (PaP-eRs).

A CoRe is a table which sets out to represent science teachers' understanding of the content for a particular topic (see Table 1 in the Appendix for an example of a completed CoRe by the participant described in this study). It does this through asking teachers to consider the central or "Big Ideas" of the topic being taught — that is, what are the essential tenants of the content that students are to learn. These "Big Ideas" form the column headings. The rows consist of eight prompts which aims to reveal the teachers' reasoning behind pedagogical choices/activities, knowledge of their students (such as alternative conceptions, difficulties, and points of confusion) and ways of assessing student understanding.

PaP-eRs are linked to the CoRe. A PaP-eR attempts to draw out aspects of a teacher's PCK in action (see Table 2 in

the Appendix as an example of a completed PaP-eR by the participant described in this study). They are a detailed description and reflection of a teacher's reasoning and thinking about one particular lesson based on a particular part of the content from the CoRe. A paper is commonly presented as narrative account of the lesson from the teacher's perspective: what did they do and why did they do it? A PaP-eR by itself does not represent the complexity or complete picture of that which makes up a teacher's PCK for that content, however a collection of PaP-eRs can certainly go further toward exploring the differing elements of PCK for that content (Loughran, *et al.*, 2004).

Loughran and colleagues, therefore, believed that through a combination of a CoRe and its associated PaP-eRs 'teachers' PCK becomes evident through making explicit the nature of their pedagogical reasoning and the associated decision making within the context of teaching particular science content' (Loughran, *et al.*, 2012, p. 21). In this regard, they believed that a Resource Folio represented solid, concrete portrayals of science teachers' PCK.

It is the purpose of this paper to examine one particular beginning science teacher's completed CoRe and PaP-eR and to provide an analysis of his thinking behind his practice. It should be noted upfront that the content area of the CoRe and PaP-eR presented in this paper is on Space. Although not a chemistry topic, the intent of this paper is to show how PCK can be developed with beginning primary teachers, and that it can be applied across all science domains. It is also an attempt at clearly elucidating explicit and concrete examples of his developing PCK as a beginning teacher, and in so doing validating whether CoRes and PaP-eRs achieve this end. If so, then CoRes and PaP-eRs have a significant contribution to improving how science (including chemistry) might be taught and learned.

Methodology

This paper reports on one specific, individualized case of a beginning primary science teacher (pseudonym of Gordon) in his first year of teaching. However, Gordon, along with five other practising science teachers (one primary and four secondary teachers) were involved in a much broader research study. This study explored how an understanding of PCK, as conceptualized through a CoRes and PaP-eRs approach, might develop science teachers' knowledge of their professional practice (*cf.* Bertram and Loughran, 2012; Loughran, *et al.* 2012). Gordon was the only participant in the study who was a beginning teacher and therefore the only candidate on which to report here in this paper. At the time of initial data collection, Gordon had only been teaching for six months. He was teaching a Grade Five and Six level composite class as a generalist classroom teacher in a government, co-educational, primary school in Australia. Previous to teaching, Gordon had gained a Bachelor of Arts, majoring in journalism and had just graduated with a Graduate Diploma of Education the year before. He had no formal training in science. When asked how confident he was when

teaching science content he said “reasonably confident” but admitted that he liked to “stay a day ahead” of the students (Gordon, initial interview).

It is important, then, that the methodology used in this larger study is reported here so as to make it clear how Gordon’s CoRe and PaP-eR were developed and analysed. The larger longitudinal, ethnographic study was undertaken over two years and focussed primarily on the use of qualitative data obtained from extensive interviews at all stages (pre-, mid- and post-study) and the development of CoRes and PaP-eRs. In terms of the reliability of both self-report data (i.e., in completing their CoRe) and the interviewing process (used in developing their PaP-eR) — i.e., did the participants provide data or frame their responses in ways which they believed the researcher wanted to hear? In order to overcome this threat, internal validity checks were routinely undertaken, such as that participants were provided with all data and interview transcripts to ensure that their views were represented as intended and that the researcher’s opinion, analysis and feedback was fair. This thereby mitigates any strong threats to validity and reliability for this particular methodology.

Creating and analysing the CoRe

Gordon was introduced, in an individual interview, to the idea of PCK and also to the framework of CoRes and PaP-eRs. He was provided with a photocopy of Chapter 4 from Loughran and colleagues’ book *Understanding and developing science teachers’ pedagogical content knowledge* (Loughran, Berry and Mulhall, 2006, pp. 31-58) which offered a completed example of a Resource Folio, presenting one CoRe and eight PaP-eRs (on the topic of particle theory). Gordon was then electronically sent a blank CoRe template (in the form of a Microsoft Word document) to complete.

Several months after this interview, Gordon submitted his completed CoRe via email. He had not required any assistance in its production. In fact, he had mentioned that it was a relatively easy process (i.e., that the CoRe’s prompts were clear and easy to understand) but that it was hugely time-consuming.

The CoRe itself was a data source — a window into capturing and portraying Gordon’s PCK. Through interpretation of the responses to the CoRes’ prompts, a picture which represented his thinking about aspects of PCK could be formed. On analysing his CoRe, observations were made and organized using each of the CoRe’s prompts as a header. After a comment had been made under each prompt-header, a brief summary was created. By filtering through all the analyses and comments at each prompt it was possible to capture insights into his PCK. These insights (which were labelled as ‘probable PCK insights’) were arranged as a concluding summary. In this paper, Gordon’s CoRe is presented (*cf.* Table 1 in the Appendix), followed by a discussion of his responses in his CoRe and finally a summary of his probable PCK insights are offered.

Creating and analysing the PaP-eR

A PaP-eR was developed for Gordon via a separate interview. This interview centered on collecting the raw data (from which the PaP-eR would be formed). In the interview, Gordon was asked to recall one teaching episode that they had recently taught which was related to the content from his CoRe. In recalling this episode, he was asked questions which guided him in remembering specific moments, decisions, and reasons for his actions in that lesson; and how he had thought about his students, the content and his own practice. The idea of these questions was to encourage rich narrative accounts which are known to more likely uncover teachers’ tacit knowledge of their practice.

After the interviews were transcribed, the next step was to transform the raw interview into a PaP-eR. It was not necessary to present the PaP-eR in the same format as that presented by Loughran, *et al.* (2006). Their PaP-eRs were presented as neat, compact and succinct edited portrayals of a lesson written in the teacher’s voice. As Loughran *et al.* (2006) explained ‘the format of a PaP-eR is responsive to the type of situation it is attempting to portray’ (p. 24). The Loughran, *et al.* version of a PaP-eR merely sought to benefit *the reader* (i.e., other teachers). Mulhall, Berry and Loughran (2003) also described that the intention of PaP-eRs was to ‘elaborate and give insight into the interacting elements of the teacher’s PCK in ways that are meaningful and accessible to the reader, and that may serve to foster reflection in the reader about the PCK under consideration, and to open the teacher reader to possibilities for change in his/her own practice’ (p. 9). PaP-eRs were intended to capture instances of PCK in action and in this study, to do so involved capturing such instances in verbal narrative form. The intention of PaP-eRs is maintained but the manner in which they have been constructed (as a consequence of the demands on participants in this research) is of one predominant form (narrative) rather than the richer array offered by Loughran, *et al.* (2006).

To create Gordon’s PaP-eR in final form, his interview transcripts were edited with a focus on one particular aspect of his practice. All unnecessary parts that were not related to this one aspect were removed; and his responses were paraphrased so that the dialogue was easy to follow. The final PaP-eR was still presented in an interview format (see Gordon’s PaP-eR, Table 2 in the Appendix).

Since a PaP-eR is already a form of PCK in itself, the difficulty in analysing it lies within accurately portraying the PCK for what it is. If too much analytical detail is drawn out then the risk is that it becomes dominant and the value of the importance of the big picture is diminished. So, after going through Gordon’s transcript, anything which was felt to be interesting or stood out, a call-out box describing what had been found was inserted. In this way, the comments do not compromise or affect the original flow of ideas of Gordon’s commentary in the interview. At the end of each transcript, all the call-out boxes were gathered to produce a list which could be considered to be representative of his PCK (these

were again called ‘probable PCK insights’ — similar to the list produced in the analyses of his completed CoRe). It is important to note too that the majority of call-outs throughout the transcripts were not all PCK insights — they were often some interesting points that were felt to contribute towards understanding how Gordon viewed his professional practice. After creating this list of ‘probable PCK insights’, the insights were analysed and comments on how his PaP-eR linked to their CoRe were offered. Each individual case then concluded with how their PaP-eR tied in with PCK and whether Gordon felt that he had benefited from the process of its creation. In this paper, Gordon’s PaP-eR is presented (*cf.* Table 2 in the Appendix) followed by a brief discussion, and finally a summary of his probable PCK insights.

Findings and discussion on Gordon’s CoRe

Gordon’s CoRe

In the study, Gordon completed his own individual CoRe. This CoRe focussed on the topic of Space which was intended for his composite class of Grade Five/Six students. His CoRe (*cf.* Table 1) is presented in the Appendix. As mentioned previously, while the content has a physics focus there are teaching and learning implications here that are applicable to the teaching of chemistry.

Interpretation and discussion on Gordon’s CoRe

This section presents a discussion and (likely) interpretation of Gordon’s responses at each of his CoRe’s prompts (as presented in Table 1). The idea behind so doing is that perhaps CoRes offer a way into a *beginning* science teachers’ thinking about their professional practice (and, therefore, begin to articulate or portray their developing PCK). A summary of probable PCK insights which emerged from these discussions is also provided.

It has been noted in the literature how difficult it can be to conceptualize the Big Ideas of science teaching (Osborne, Collins, Ratcliffe, Millar, and Duschl, 2003). In line with this view, other participants’ Big Ideas (in the larger study) were not really big ideas in terms of the way described (or expected) by Loughran, *et al.* (2006). Rather they were titles for smaller content areas contained within the overall topic. These titles were perhaps created in this way by the participants because they were similar to how text books or curriculum documents outline the main topics in a subject area. Gordon’s Big Ideas, however, were more in tune with ‘content ideas’ rather than ‘content areas’. Gordon had claimed (in a follow up interview for the larger study) that he had negotiated the Big Idea topics with his students and listened to what they had wanted to learn. He had constructed the Big ‘Science’ Ideas in response to these views of the content:

Researcher: How did it [the CoRe] get you to think about your students’ needs specifically when it came to Space?

Gordon: ... The initial first step that I did was to enter into a

discussion with the kids as a whole class. And I had them actually write down some areas of interest for themselves and ... find out what the students: A — were interested in and B — what their questions were. [This] allowed me to develop curriculum that was more relevant to them. And so, I had them write down their questions on a star. ... But some of the kids were asking questions, such as ... ‘How do rockets work?’ ... ‘What’s the deal with Earth and the other planets and their rotations and things like that?’ So ... from those conversations, it developed into a unit of work, basically. And I already had basic templates of where I wanted to go with the unit but this provided something that would be more relevant for the students.

(Extract from Gordon, follow up interview)

Generally, Gordon’s responses were a good attempt at addressing the CoRe’s prompts. While some lacked detail or were not substantiated (perhaps due to his inexperience as a teacher), others provided rich insight into his thinking behind his practice. The latter part of the CoRe’s last prompt was, however, poorly addressed. For this prompt, ‘Specific ways of ascertaining students’ understanding or confusion around this idea (include a likely range of responses)’ Gordon did not provide any comments on student confusion nor ‘a likely range of responses’ at all. Perhaps this question required too much effort or involved difficulties that Gordon was not yet prepared to discuss with any specific detail.

Having said that, it was still possible to gain insight into and snapshots of Gordon’s PCK. Therefore, it seems reasonable to assert that the structure of a CoRe can indeed help to uncover and explore aspects of PCK of a beginning teacher.

What do you intend the students to learn about this idea?

Gordon’s responses at this prompt were general and did not provide specific detail. For example, under Big Idea A (“How rockets work”) Gordon simply wrote, ‘I want the children to have an understanding of how rockets propel themselves out of the Earth’s gravitational pull’ (Gordon’s CoRe, Big Idea A). Interestingly though, it appeared that one of Gordon’s intentions concerning what he would like his students to learn was not specific to the content as such but was specific to particular sets of learning skills or abilities. In Big Idea B (“Why does the Sun look red at sunset?”) Gordon stated that, ‘I intend to create an experiment where the children question something that is routine, such as a red sunset... There will be an opportunity for some enquiry-based learning to advance the children’s ability to locate and understand information too’ (Gordon’s CoRe, Big Idea B). So, perhaps, his responses were not at all about questioning the science behind why sunsets are red but, for Gordon, it was about how he offered students the chance to research and discover answers for themselves. For other Big Ideas (Big Ideas C and D), Gordon’s intention was to clarify content with which he believed his students may experience difficulty.

Why is it important for students to know this?

When Gordon answered this particular prompt, the reasons behind why he thought it was important for students to know, apart from Big Idea D, did not focus on the content. For Big Idea D, Gordon believed that it was important for students to know about the content because he felt that students had a poor understanding of the concept of night and day. For the other Big Ideas he mentioned the importance of the teaching procedure used rather than the content itself. For example, in Big Idea A, Gordon felt that students would 'have more of an association to the texts' if they were able to 'design and race their own rockets' (Gordon's CoRe, Big Idea A). He felt that this was important for 'relational understanding' (Gordon's CoRe, Big Idea A). In Big Idea B, he explained that enquiry-based learning was important to students' understanding and that his students 'have been responding with 'wonderment and awe'' (Gordon's CoRe, Big Idea B) with this approach.

What else do you know about this idea (that you do not intend students to know yet)?

For Big Ideas A and B, Gordon listed some areas of the content which he felt may be too complex for students to grasp. His response to Big Idea C was not related to the prompt — instead it offered his intention about how he might further investigate the content with another activity.

What are the difficulties/limitations connected with teaching this idea?

At this prompt, Gordon listed some practical difficulties (such as not having an adequate financial budget to make space shuttle models). He also commented on concepts which he believed students might find difficult or abstract (such as the reasons for different time zones at different locations around the Earth). Gordon claimed that students 'at this age tend to be very visual so verbal discussion of this may make it too abstract a concept' (Gordon's CoRe, Big Idea B). From this, it is likely that Gordon believed that students needed visual aids or models to assist in their learning of some concepts because of their age. Gordon expressed disappointment at not being able to have a model space shuttle because he claimed that 'some of these children are very kin-aesthetic learners' (Gordon's CoRe, Big Idea A).

What is your knowledge about students' thinking that influences your teaching of these ideas?

At this prompt, Gordon's responses focussed on his students' difficulties in understanding the content. He proposed ways of addressing this issue with his belief that student learning was enhanced with hands-on models. He also stated that providing opportunities for group-work and discussion amongst students was 'vital as often children can explain their understandings in ways that the children who are struggling will 'get'' (Gordon's CoRe, Big Idea A).

Are there any other factors that influence your teaching of these ideas?

At this prompt, Gordon mentioned practical issues such as consideration of the learning environment for different activities. More importantly, he explained how he assisted both slow and advanced learners with differing and varied activities. Gordon also mentioned that he expected students to form their own various and different conceptions about the content; and that he understood that some students would understand earlier and more easily than others.

What are your teaching procedures (and particular reasons for using these to engage with this idea)?

Gordon described a variety of teaching procedures with a basic description of what was involved. He did not often, however, explain the particular reasons for using the approach described. In some instances, he explained that the procedure was used for visual learners or weaker students or for evaluating students' understanding. Interestingly too, Gordon stated that he did 'physical' (Gordon's CoRe, Big Idea D) activity specifically during the afternoon because 'children get restless' (Gordon's CoRe, Big Idea D).

The types of teaching procedures which Gordon claimed he used included thinking tasks (such as the Wondering Wall and Predict-Observe-Explain procedures), physical modelling and experimentation, visual computer-aided modelling and student group discussions. Many of his descriptions of his teaching procedures did not explicitly link to the particular Big Idea to which they were listed under. For example, his use of modelling sunsets in Big Idea B with milk and water was not well explained as to how it modelled red sunsets.

Specific ways of ascertaining students' understanding or confusion around this idea (include a likely range of responses)

Gordon listed formal assessment as part of his way of ascertaining his students' understanding. Such assessments included an end of unit test and written responses to prompts. He also claimed that he used 'observations, anecdotal notes, work pieces and general discussion' (Gordon's CoRe, Big Ideas A to D) in evaluating students' understanding for all of his Big Ideas. Gordon did not offer any issues about students' confusion nor did he provide any likely range of responses.

Summary of probable PCK insights from Gordon's CoRe

In interpreting the analysis above, aspects of Gordon's developing PCK for this content area could include the view that:

- through negotiating certain elements of this particular content with students (i.e., the students had input into the content to be taught) the unit could be more relevant for them;
- enquiry-based learning offered students the chance to research and discover answers on their own, which appeared

to foster ‘wonderment and awe’ (Gordon’s CoRe, Big Idea B) for this particular topic;

- difficult or confusing terminology needed to be carefully explained;
- particular teaching procedures (included thinking tasks such as Predict-Observe-Explain) could enhance student learning for this particular content. Gordon explained that one such teaching procedure was important for ‘relational understanding’ (Gordon’s CoRe, Big Idea A) which could potentially equip students with skills for furthering their knowledge about this particular topic. He also explained that particular teaching procedures should be employed to cater to different students’ (advanced or weaker) learning abilities;
- Grade 5/6 students (because of their age) benefited from visual aids or models to assist in their learning of some concepts about this particular content. Some students also benefited from kinaesthetic activities;
- he expected students to form various and different conceptions about this particular content. He understood that some students would understand earlier and more easily than others; and,
- students’ understanding could be ascertained through formal assessment and ‘observations, anecdotal notes, work pieces and general discussion’ (Gordon’s CoRe, Big Ideas A to D) for this particular content.

Findings and discussion on Gordon’s PaP-eR

This section presents Gordon’s PaP-eR (*cf.* Table 2 in the Appendix) which is based on a specific lesson around his Big Idea, ‘How rockets work’, from his CoRe. The PaP-eR is introduced by a brief overview which provides a quick summary of the PaP-eR and highlights the insights, ideas and approaches used by Gordon in teaching particular content in one particular teaching episode.

Interpretation and discussion of Gordon’s PaP-eR

An analysis of Gordon’s PaP-eR is provided here in an attempt to highlight the most noticeable aspects of his developing PCK as illuminated through his PaP-eR above. This analysis is restricted to Gordon’s views which are clearly linked in terms of both their teaching and the content. A list of probable PCK insights is then offered as a final summary of Gordon’s PCK in teaching this particular content to his particular students.

As can be seen from his PaP-eR, Gordon was very much in tune with the notion of PCK. His responses demonstrated that he was consciously aware of his own teaching and learning and he was amenable to exploring what that might mean for the development of his professional knowledge. His PaP-eR richly captured and explored aspects of his developing PCK. In the specific instance of how he assisted one particular student, he described the great importance in knowing his students: to understand their abilities and limitations; and, as a necessary consequence, to tailor learning activities for their specific needs:

I think every classroom — when you’re doing maths sessions or literacy sessions — should be tailored towards the learning needs of the students, more so than just the teacher’s needs and getting the content out there. It takes more time in your planning but I think, really understanding the content and making it relevant [is important]. You need to look at your students and assess it all the time. So, it needs to be fluid. You wouldn’t have a student in the same group all the time — it needs to be reflected upon and moved around quite frequently. (Gordon’s PaP-eR)

This activity was related to Gordon’s Big Idea A (“How rockets work”) from his CoRe. Although, it contains little of the content-related issues which were discussed in his Big Idea, it is an elaboration of a very specific instance of a teaching episode that occurred based on the content.

As a result of his PaP-eR, Gordon came to acknowledge and appreciate the benefits of having an awareness of PCK — that he was able to see it in his own teaching and, therefore, use it to develop his own professional knowledge. This PaP-eR helped him to see, through reflection, aspects of his own teaching and learning: ‘you’re learning the content, you’re learning how you are teaching, you’re learning your style and the style of the kids around you’ (Gordon’s PaP-eR). It could also be suggested then that PaP-eRs create possibilities for Gordon to *value* what he did in his lesson and invites him to develop insights into his professional knowledge.

Summary of probable PCK insights from Gordon’s PaP-eR

For Gordon, this activity allowed him to develop his PCK even further. Aspects of his PCK could include his view that:

- a ‘fun’ activity could foster student engagement and make this particular content relevant to his students;
- individualized activities could evoke ownership of learning in his students and, therefore, their learning might be enhanced;
- his teaching approach was flexible and that students were allowed input about the direction of the lesson for this particular content;
- students needed to feel validated, listened to, cared about and valued. In turn, they might be more amenable to learning; and,
- it was important that he could clearly identify with and understand his students’ particular learning abilities (including their weaknesses). He placed much emphasis on tailoring specific learning activities for particular students because he believed that this content was made more relevant to them. He believed that this was more important than his own needs as a teacher, and he acknowledged that he should remain fluid in his approach and adjust it when necessary.

Discussion

It was expected that through an analysis of a CoRe and

PaP-eRs framework, a clearer picture of the beginning teacher's thinking behind his practice would be revealed. In particular, could it be possible to clearly articulate and portray aspects of his developing PCK too? This paper has revealed that, through an examination of Gordon's CoRe (Table 1) and PaP-eR (Table 2), that a CoRe and PaP-eR approach can work in this regard, in that specific aspects of his practice point toward probable (or *are* definite) instances of his developing PCK. Even with his limited science content knowledge it appeared that the CoRe and PaP-eR were able to help him connect the little content knowledge he had with his pedagogic knowledge in ways that assisted him in forming a small snapshot of his PCK.

It appears then, that even beginning teachers (with at least some teaching experience) can actually possess limited but foundational PCK, which, while in its infancy, could form the base of future and more substantive PCK development. This is a significant finding and contribution in advancing PCK research in the field of science education.

For Gordon too, the actual process of being involved in the development of a CoRe and PaP-eR, has offered him a better way of seeing into his professional practice, especially in his position as a beginning teacher. Working through a CoRe and PaP-eR like this was a learning experience that began to make real the notion of his PCK. While it could be argued that 'real' PCK insights probably do not emerge until his thinking about teaching and learning is more fully developed, especially with more teaching experience, it has at least captured those most pertinent and salient features of an early and formative understanding of his own PCK. In this regard, a snapshot of a beginning science teacher's PCK can be clearly seen to exist, but perhaps nowhere nearly as extensively developed as that of experienced science teachers (*cf.* Bertram and Loughran, 2012, which explored the PCK of experienced science teachers through using a CoRes and PaP-eRs approach). Gordon's CoRe and PaP-eR is perhaps an exemplar that PCK can be viewed from this differing perspective relative to experience.

Also, the tacit nature of PCK has well been recognized as a problem in identifying it explicitly. As presented in the introduction: 'Teachers' PCK becomes evident through making explicit the nature of their pedagogical reasoning and the associated decision making within the context of teaching particular science content' (Loughran, *et al.*, 2012, p. 21). Upon considering this in the articulation of PCK, this paper has provided evidence that CoRes and PaP-eRs do just that. This paper has illustrated that CoRes and PaP-eRs prompted the beginning science teacher to meaningfully reflect on his practice. This then led to an improved 'language of practice' which in turn positively influenced his ability to communicate his views of teaching and learning in meaningful ways. Hence his understanding of PCK was better developed, and as a consequence, his professional knowledge of practice was essentially enhanced and that this has indeed highlighted and contributed toward constructing improved knowledge of teaching science that is definitely

beyond normal beginning teacher thinking and more than just that gained via normal teaching experience alone.

Conclusion and Implications

This paper has shown that it is possible to articulate (probable) aspects of a beginning primary science teacher's developing PCK using CoRes and PaP-eRs as a useful heuristic. This has not been investigated to this extent in the science education research literature. CoRes and PaP-eRs not only offer a way of scaffolding and capturing beginning teachers' PCK but also assists in developing their general knowledge teaching and learning, in regard to professional practice. This finding is significant in the context of pre-service or initial science teacher education, as it may assist teacher-educators in deliberately embedding the notion and ideas about PCK in their programs in an effective manner. Given that CoRes and PaP-eRs have been demonstrated to be an effective tool in so doing through this study, and thereby validating Loughran and colleagues' work, it does give rise to a number of research possibilities. As Kind (2009) contended, CoRes and PaP-eRs could be invaluable to science teacher research. Such studies are already underway in pre-service science teacher education in the area of chemistry (*cf.* Loughran, Mulhall, and Berry, 2008; Nilsson, 2010) and also with practising science teachers teaching chemistry (*cf.* Garritz, Porro, Rembado, and Trinidad, 2007; Hume and Berry, 2011; Ratcliffe, 2008; Rollnick, *et al.*, 2008). Other possibilities, however, could include more substantial and longitudinal studies into analysing how CoRes and PaP-eRs might be used as a heuristic in developing and supporting beginning science teachers' PCK, not just of chemistry but all science domains.

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Appendix

Table 1. Gordon's CoRe on Space.

Year level: Grade 5 / 6	<i>Important science ideas / concepts</i>			
	Big Idea A How Rockets Work	Big Idea B Why does the Sun look red at sunset?	Big Idea C Earth and other planets orbit	Big Idea D Planet Earth Day and Night
Content area: Space				
<i>What do you intend the students to learn about this idea?</i>	We are learning about various aspects of Space travel, such as the Challenger Disaster, in coming weeks. I want the children to have an understanding of how rockets propel themselves out of the Earth's gravitational pull.	I intend to create an experiment where the children question something that is routine, such as a red sunset. Why is the sunset red? There will be an opportunity for some enquiry-based learning to advance the children's ability to locate and understand information too.	As mentioned in the previous Big Idea, some of the students are having trouble grasping the notion that Earth orbits around the Sun. Some students have also asked if the moon orbits around the Sun too, rather than understanding that it is a natural satellite that orbits the Earth.	Building upon the concepts learnt in previous lesson, and having thought about the orbit of the Earth around the Sun, I want the students to understand and to be able to explain how the rotation of the Earth results in different parts of the Earth experiencing day and night.
<i>Why is it important for students to know this?</i>	Relational understanding. If the children are given a chance to design and race their own rockets then I hope they will have more of an association to the texts we are about to read.	Enquiry-based learning is a common approach in this class as the children in this classroom are very inquisitive. Linking this lesson to a question which a child asked last week demonstrates that their questioning attitude is to be encouraged, and indeed the children have been responding with 'wonderment and awe' during this unit.	This revision of orbits, particularly with Earth and the Sun, are designed to show that each planet has its own orbit around the Sun.	I have received some student questions about whether it is day or night in other parts of the world as opposed to Australia. Given this lack of understanding, I felt it was important to explore this concept as a whole class.
<i>What else do you know about this idea (that you do not intend students to know yet)?</i>	Some of the complications associated to space travel. For example, in the media at the moment Discovery is unable to re-enter the atmosphere because there is small tear in the protective shielding. We will discuss and explore this further in literacy activities.	As this is more or less a stand alone issue we will explore it in the lesson through research and discussion. There is nothing further that I intend to add to this lesson unless additional questions arise that I had not thought of.	This lesson will lead to a basic experiment for the students to do to look at the concept of how night and day works with the Earth and its orbit around the sun.	
<i>What are the difficulties/ limitations connected with teaching this idea?</i>	I have not introduced the detail associated to space shuttles, such as the names of certain sections. I don't have a model space shuttle I can use as an example as there is no budget. Although this can be overcome with an overhead image. Some of these children are very kinaesthetic learners.	The notion that the Earth is enclosed in air and full of bits of dust and water drops too small for us to see may make this a hard concept for the children to grasp. Again, children at this age tend to be very visual so verbal discussion of this may make it too abstract a concept.	At the lower end of the spectrum some students do not understand that the Earth orbits the sun. On the other hand some students know this already, so I have had to plan extensions to this task for those students.	As with all lessons in the classroom some students are more advanced in their understandings than others. I created a range of Space Missions for these children, such as comparing a particular time in Melbourne with Toronto and having them represent it in 24 hour time.
<i>What is your knowledge about students' thinking that influences your teaching of these ideas?</i>	These children are 10-12 years old, so the way they come to understand can be very different. Providing opportunities for small group-work and discussion is vital as often children can explain their understandings in ways that the children who are struggling will 'get'.	Many students are still grasping concepts, such as the notion that the Earth revolves around the Sun and not the other way around. In order for the children to gain a better understanding about the big idea I will use a hands-on science experiment as an opportunity for them to develop their understanding.	Many students have difficulty understanding less immediate concepts and so I have created a hands-on activity to aid the students in their understanding. As some of the kids would be able to create a model of the Earth orbiting the Sun very easily I have also included an extension task for those students to create a model of the Sun being orbited by Earth and one other planet.	The students will use a physical model that we will create together so they can understand how the Earth's orbit creates night and day in different places around the world. This physical and visual representation will aid the children who do not understand this concept.

Table 1. Gordon's CoRe on Space (*continues*)

Year level: Grade 5 / 6	<i>Important science ideas / concepts</i>			
	Big Idea A How Rockets Work	Big Idea B Why does the Sun look red at sunset?	Big Idea C Earth and other planets orbit	Big Idea D Planet Earth Day and Night
Content area: Space				
<i>What are your teaching procedures (and particular reasons for using these to engage with this idea)?</i>	<p>Generate open-ended discussion. I will say "How can we create a space shuttle race?" This helps to generate interest as the students ideas are being listed and discussed. I will take out the materials required (straw, fishing wire, paper bag, balloon and sticky tape) and ask the children how these materials might be used for an activity now. Write down in their project books. Hand out 'Procedural Text' (something we are also focussing on in literacy – hence the tie in) that explains how space shuttles operate. The text also includes a visual image for those students who are visual learners. Students create their rockets, designing a ship on the paper bag. After having 10 minutes to create and design their rockets are raced to see whose goes the furthest.</p>	<p>Predict-Observe-Explain (POE): What do you think will happen when we add one teaspoon of milk to the glass jar filled with water? Why? What will happen if we place a torch to the side of the glass jar? Students predict what will happen by having time to write down their ideas and then chatting about them.</p> <p>Stand up, Hand up, Pair up: Students move around the room and find someone they haven't worked with. Once they find another student they give them a high five. This provides an opportunity for a child to practise expressing their thoughts to a range of different people.</p> <p>Modelling with specific materials: certain materials will be provided so that the children can analyse their predictions.</p> <p>Observation: What is happening to the glass jar when we stir in one teaspoon of milk?</p>	<p>I set up a Wondering Wall at the start of this lesson, relating to the key word 'orbit'. This allowed me to check their understandings and to find out what misconceptions some of the students had. I choose this because the students cover a range of areas, and by reading the questions out they can assist each other too.</p> <p>Children with a poorer understanding constructed a model of the Sun, Earth and the moon. The instructions were both verbal and written to accommodate the students learning needs. Other children were given a Space Mission, a concept I have created for those students ahead of the others in their understandings. These students constructed a model of the Sun, Earth, Moon and another planet. They had to explain the difference in time it took to orbit the Sun and how it is they found this out.</p>	<p>Before we did a physical activity the students were given a map of the world. They were given instructions about the time in Australia and depending on the location given they had to decide whether it was night or day at the time. As this was an afternoon lesson the children had to act out an activity from either day or night that was relevant to a certain country. I choose this because the children get restless during the afternoon.</p> <p>We then used a computer program and the overhead projector to look at an example of time zones from a particular website. This was useful in checking their estimations and predictions about the time in Australia and other locations in the world.</p> <p>The children also created a physical model of day and night, using a balloon, a rough map of the world on it and a torch.</p>
<i>Specific ways of ascertaining students' understanding or confusion around this idea (include a likely range of responses).</i>	<p>We will discuss which students' rocket in that day's literacy rotation won and why. More immediately the children will track their own understandings. On the board I will write "I used to think ..." as a prompt to generate a written response on a post it note, which I will then add to a display, along with the rockets they've created.</p> <p>The whole unit is also tested at the end by a space test. Other than that there are observations, anecdotal notes, work pieces and general discussion that allows for students' understandings to be assessed.</p>	<p>At the end of the unit there will a space test, in which the children are able to include any knowledge they have learnt. Listening for student questions.</p> <p>There are observations, anecdotal notes, work pieces and general discussion that allows for students' understandings to be assessed.</p>	<p>Observations, anecdotal notes, work pieces and general discussion that allows for students' understandings to be assessed.</p> <p>Accuracy of their model and an ability to explain what they have created to their peers.</p>	<p>The student model was used as a guide to ascertain students' understandings. Observations, anecdotal notes, work pieces and general discussion that allows for students' understandings to be assessed.</p>

Table 2. Gordon's PaP-eR.

Introduction to the PaP-eR (Related to his CoRe's Big Idea A: "How rockets work")	
<p>In this PaP-eR, the teacher recounted an activity which focussed on how rockets worked. More specifically, the teacher explained how he especially catered to the particular learning needs of one student. This PaP-eR provides rich insight into the teacher's thinking and reasoning underpinning his beliefs of teaching and learning in this unit.</p>	
Gordon:	<p>Our overall unit for the term was Space. ... It was all tied into literacy as well, so it was a very integrated curriculum that I teach. We were about to look at space shuttles and rockets and some different events that had happened, such as the Columbia space disaster. For the students to grasp that and make it more relevant, I wanted [them] to understand how rockets were propelled, and I thought of a fun way to do that.</p>
	<p>Here, Gordon associated a 'fun' activity with making this particular content relevant to his students.</p>
	<p>Very, very simple: fishing line, balloons, straws, a paper bag and that was basically it. They're the materials. I had a [work]sheet and we talked about it and then the students actually got to follow the instructional piece of writing and design their own spaceships — just as a means of making it more individualized.</p>
	<p>It seemed likely that Gordon believed "individualized" activity allowed students to own their learning.</p>
	<p>The students got to build their own rockets and we had races. You know, they love to be competitive ...</p>
	<p>This is an insight into how he used this activity to foster student engagement (under the guise of 'fun') as a means of connecting students with this particular content.</p>
I:	<p>What did it feel like teaching, ... [in terms of] pedagogical content knowledge specifically?</p>
Gordon:	<p>It was very beneficial ... It was good for me because I thought it would increase my own knowledge ...</p>
	<p>Gordon appreciated the benefits of having an awareness of PCK and what it did for his own professional knowledge.</p>
I:	<p>I want to know more about what you taught and how you taught it. Can you think now of a specific instance where a student may have asked you a question and then how you went about answering it?</p>
Gordon:	<p>The kids wrote their questions on a star — one of the questions that was asked was, "How do rockets work?" So, I wanted to try and answer that question and I had to go back and obviously research it because I don't personally have experience with flying rockets. So, I devised this way of communicating to this student, as well as the others — a way that was more relevant, and the child that asked this particular question ... doesn't really do very well if you verbally tell him something. He needed to develop it for himself and so the instructional piece of writing that I developed for the kid, and that I gave to the other children as well, allowed him to understand how rockets worked better than me just standing there telling him or writing it on the board.</p>
	<p>This paragraph is clear evidence of Gordon's consideration of how best he catered to specific individual learning needs. It demonstrates how he understood his students' abilities and way of learning. In this regard, the activity was not superfluous — it was well thought about and crafted.</p>
	<p>So, I was answering that kid's specific question as an example. There were other questions, obviously from the twenty-four children, and some of them had more than one question. In some instances, I had the other kids, in their literacy groups, answer another child's questions and they shared the knowledge together. And in other instances where I thought that the question had occurred many times, then I would pinpoint it to the whole group and we would do an activity based on those questions.</p>
	<p>Gordon kept his teaching approach flexible in this task, allowing students to guide the direction of the lesson.</p>
I:	<p>What indications were there to you that the kid actually understood?</p>
Gordon:	<p>Yeah, good question. We talked about propulsion and how rockets fly, and [the child] actually talked to me at recess afterwards and he just seemed interested in the topic ... So, once we had done that lesson, he had just wanted to talk about it some more. And that interest in what we were doing was really great to see — even though it took up my recess — but it was really great to see that he wanted to follow it up and discuss it some more.</p>
	<p>Gordon appeared to be excited when he discovered that learning had taken place in his students. This perhaps reveals something about his teaching attitude for this particular topic.</p>
	<p>And then I think it was further enhanced when we looked in the literacy books about the space shuttle, challenges of sending a space shuttle up and the disasters and everything. And then at the end of the term, we did the post-test. And when I looked at the post-test he had mentioned how rockets fly and different disasters that he had read about and things of that nature. So, obviously, sort of surprisingly too, it had actually stayed with him and he remembered some of the content and he was able to, several weeks later, write down what it was that he learnt.</p>

Table 2. Gordon's PaP-eR (continues ...)

I:	So, what do you attribute then to that recollection of a story, that gave you the notion that you had identified a PCK moment in your teaching?
Gordon:	(Long pause). I suppose ... it can be something as simple as a nod of the head. In this case, it was as simple as the kid actually staying behind and chatting to me about it, when I don't think he's ever done that before. So, I feel like the content and my knowledge of it, was relevant to the student and knowing the individual student's needs.
	Gordon acknowledged a powerful PCK moment. He realized that the content was made relevant to his student because of the way he tailored the learning activity specifically for him. He could further ascertain that the student had learnt the content from follow up conversations.
	I think ... for this particular student, who has had difficulty throughout the year ... would have felt, I suppose, satisfied in one sense because I'm listening to his question on the star. And I made a point of saying, "Ok, today we're going to be addressing Student A's question" and I think also he probably felt like his queries were more valid as well, and that the teacher was listening to him as a student. So, I think that's a great benefit but also just to know that the teacher cared about what he thought as well, is very important. ... I hope he went home and said, "Oh, mum, today ...", you know ... "I learnt about rockets". ... I don't know that he did but I'm hoping that he might have taken that knowledge home and shared it with his older brother or his mother.
	This whole paragraph encapsulates Gordon's belief that students needed to feel validated, listened to, cared about and valued. In turn, students might be more amenable to learning.
	It appeared that a measure of learning for Gordon was his students' willingness to discuss what they had learnt.
I:	So ... evidence of a PCK moment for you would be manifested, perhaps, by a student wanting to tell someone else about what they have learned today?
Gordon:	Oh, absolutely. Yeah. I had many reports from parents throughout the year ... and the children going home and sharing that knowledge with their parents and then the parents would talk to me about it and go ... "It was really great for Student X to learn this stuff in class and then come back".
I:	You talked very specifically about one particular student in that class. ... He's one of many and I was just wondering if PCK had emerged or become visible to you for any of the other students in that class besides just that one boy?
Gordon:	I think that throughout the year, that was the case with all the students. I was always very aware with my planning of the content. I wanted to be quite knowledgeable in the content. But also, I wanted to be aware of how I could communicate what we were going to do to the students properly. So, I think that was probably something — without knowing the terminology [of PCK] and expressing it to the children at the time — was something that was done throughout the year.
	Gordon confirmed the importance he placed on understanding and catering to his individual students' learning needs.
I:	What have you learned [through this PaP-eR]?
Gordon:	I suppose I've learnt several things. One is that, students will have limitations but it's important not to view that as a weakness. Those limitations are something that, as a teacher, you have to approach. And you have to look at ways to get around that so that it's relevant to the student. I suppose, it's probably one of the more fundamental things I learnt. So, some students are particularly good at, say visual learning, some kids are particularly good at auditory ... whatever it might be but then they might have a weakness in another area. I can only really think of one or two students who are pretty much good in all learning areas — as I would classify them — throughout the year. The other twenty-two [students] would be good in some areas but they would struggle in another area. So, you need to be aware of how you are going to communicate what you're trying to teach to the students. And I mean, it's easier if you can approach it in learning groups — which is what I did. So, I would group the students based on ability levels and that was guided somewhat by knowing the students and understanding them and knowing the content and how I could broach it with them. And I think, personally, I don't know if this happens in high school but in primary schools that I have seen, it probably happens fifty percent of the time. It needs to happen more often. I think every classroom — when you're doing maths sessions or literacy sessions — should be tailored towards the learning needs of the students, more so than just the teacher's needs and getting the content out there. It takes more time in your planning but I think, really understanding the content and making it relevant [is important]. You need to look at your students and assess it all the time. So, it needs to be fluid. You wouldn't have a student in the same group all the time — it needs to be reflected upon and moved around quite frequently.
	This statement features a prominent and important aspect of Gordon's PCK. By acknowledging the limitations of his students' weaker learning styles, he explained how he tailored his teaching approach to their specific learning style and how he grouped them according to ability for ease of instruction. Another important aspect of Gordon's PCK is his significant claim of his students' needs above his own. He felt it vital to invest time into tailored planning to enrich his students' learning experience.
I:	You have produced a CoRe and then elaborated on it. Is this [PaP-eR] ... something worthwhile doing for all teachers? ...
Gordon:	I certainly don't see any harm in it. I don't see how it could hinder their development and the development of the children in the classroom.
	Through the process of making this PaP-eR, Gordon revealed that his PCK had been enhanced. The PaP-eR served as a reflective tool that made germane to him many aspects of teaching and learning: "you're learning the content, you're learning how you are teaching, you're learning your style and the style of the kids around you".
	Reflecting upon what you have done and ... you know, sometimes you are too busy so you can't reflect upon a lesson straight away ... but there might be something specifically you think about two or three days later or a week later and that could enhance your teaching and learning. That's relevant for teachers — you're learning the content, you're learning how you are teaching, you're learning your style and the style of the kids around you as well. And, as I said, I don't think enough reflection really happens. At no point after we taught any of the units last year, did we look at how we could improve it for the next go around. Those discussions didn't really happen.

(End of interview.)