

# Using collaborative CoRe design in chemistry education to promote effective partnerships between associate and student teachers

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## Introduction

This article is a follow-up to my paper published in 2010 (Hume, 2010). In that paper I reported on the use of Content Representations (CoRes) in a chemistry education course to give student teachers insights into the professional knowledge of experienced practitioners: notably their pedagogical content knowledge (PCK), which is "... [the] understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learning, and presented for instruction" (Shulman, 1987, p. 8). Introduced by Shulman (1987) as an academic construct to describe a tacit category of teachers' professional knowledge base, the exact nature of PCK has been extensively explored and debated. From this debate some agreement has emerged about the components that comprise a teacher's PCK. This has been identified by Magnusson *et al.* (1999) as a teacher's:

- orientations towards science teaching (since teachers' knowledge and beliefs related to their teaching goals and approaches will influence their classroom practice);
- knowledge of curriculum;
- knowledge of assessment (since what is to be assessed, how and why also influences a teacher's practice);
- knowledge of students' understanding of science;
- knowledge of instructional strategies.

Since few concrete examples of PCK were available to inform teacher education, Loughran *et al.*, (2004, 2008) explored the PCKs of a group of expert science teachers to identify any commonalities. They developed CoRes (see Fig. 1) as diagrammatic tools for depicting expert teachers' collective PCK related to the teaching of a particular science topic, e.g., chemical reactions.

In my previous study I found the existing CoRes produced by Loughran *et al.* (2004), to be very useful tools for helping student teachers understand the nature of PCK. Giving the teachers the opportunity to design their own CoRes had the added benefits of providing them with a means for constructing their own tentative PCK.

A logical continuation of this study involved investigating whether further PCK gains could be made by the student teachers by 'testing' the tentative PCK embodied in their CoRes in real classrooms with real students. The teaching practicum offered such an opportunity for them to test out their new-found knowledge, and so in the following year I made it a course requirement for student teachers to utilise their CoRe in their practicum planning for teaching chemistry. This exercise was to take place under the all-important guidance of their associate teacher, since it is well recognised that associate teachers play a crucial role in supporting student teachers as they experiment with pedagogy and reflect on their first classroom teaching experiences (Fazio *et al.*, 2010).

	Important science ideas/concepts		
	Big Idea 1	Big Idea 2	Other
1. What you intend the students to learn about this idea?			
2. Why is it important for students to know this?	PaP-eR 1		
3. What else do you know about this idea (that you don't intend students to know yet)?	PaP-eR 1	PaP-eR 3	
4. Difficulties/limitations connected with teaching this idea.		PaP-eR 2	
5. Knowledge about students' thinking which influences your teaching of this idea.			PaP-eR 4
6. Other factors that influence your teaching of this idea		PaP-eR 3	
7. Teaching procedures (and particular reasons for using these to engage with this idea.		PaP-eR 2	
8. Specific way of ascertaining students' understanding of confusion around this idea ( include likely range of responses.			PaP-eR 4

Fig. 1: CoRe (Content Representation) and associated PaP-eRs (Pedagogical and Professional experience Repertoires) (Loughran *et al.*, 2004, p. 376).

Ideally, in a form of expert-apprentice relationship during the practicum period, the experienced teachers progressively draw their student teachers into the 'more central professional activities' (Girod & Girod, 2006) of classroom teaching and learning by working collegially and in tune with student teachers' needs (Fairbanks *et al.*, 2000). Unfortunately, from the perspectives of the teacher educator and the student teacher, this apprenticeship model can sometimes fail to live up to expectations during a school-based practicum. Often the teaching style of the associate does not match the teaching and learning approaches promoted by the teacher education programme. Putnam & Borko (2000) suggest one cause of this mismatch may be a lack of mutual understanding about each party's goals and expectations of the practicum. Such misunderstanding may be avoided by better communication between teacher educators and associate teachers (Sadler, 2006), perhaps through partnerships (Fazio *et al.*, 2010).

The failure of practicum to meet expectations of teacher education programmes may also relate to the capacity/capability of the associate teacher to carry out the mentoring role required in the apprenticeship model. In a literature review of research into associate teachers' involvement in the induction of student teachers, Sanders *et al.* (2005) identified seven possible roles that associate teachers can take on during practicum: (1) model teacher; (2) observer and evaluator of teaching; (3) planner of teaching experiences; (4) conferencer; (5) professional peer; (6) counsellor; and (7) friend. However, Sanders *et al.* (2005) reported a lack of clarity in the literature about these roles and the expectations of associate teachers, which prompted them to investigate how some experienced New Zealand associate teachers were actually enacting these roles. Their research revealed that the associate teachers did perform these roles to varying frequencies and extents. For example, the majority (66%) of interactions recorded in the study revealed the associates playing out the planner and modeller roles while far less could be seen of the roles that are widely believed to promote professional learning, i.e., evaluator (13% of interactions), professional peer (6%), and conferencer (1%). Even in the planning and modelling roles, deeper aspects like questioning the rationale, structure and evaluation of curriculum, or articulating their own pedagogical practices, such as critical reflection, were not evident. Among their recommendations, Sanders *et al.* (2005) advocated provision and/or development of strategies to promote "genuine pedagogical dialogue" between associate teachers and their student teachers.

## Background to the study

In this phase of my continuing study into the use of CoRe design in teacher education I sought to facilitate stronger links between my chemistry education coursework and practicum through the introduction of CoRes to the practicum experience. As in the previous year, my student teachers had prepared a series of chemistry CoRes in collaboration with one another during our university workshop activities. However, this time they each individually prepared a further CoRe for use on the second of their two teaching practices. Each student teacher had contacted their prospective associate teacher in advance to determine which topic(s) he/she would be allocated for their senior chemistry teaching, and one of these topics became the subject of their CoRe for practicum. I believed the tentative PCK each student teacher constructed through his/her final CoRe ought to provide that individual with a strong basis for the planning and teaching of the topic on teaching practice. This CoRe might also prove to be a useful conversation starter, as the student teacher began to build a working relationship with their associate teacher. I anticipated that any input from experienced teachers was likely to improve the CoRe design process for the student teachers, since it gave them an opportunity to have their tentative PCK appraised by experienced classroom practitioners, each of whom was expected to possess and enact PCK for current chemistry teaching of the CoRe topic. With these possibilities in mind, the associate teachers were invited by each student teacher to view their respective CoRes and discuss how the CoRe content might relate to teaching the required topic on practicum. The student teachers gave their associate teachers background information authored by me, which outlined the purpose of the CoRe design task and the potential input of the associates as collaborators with the student teachers. The teachers also received the published CoRe article (Hume, 2010).

I had identified CoRe design as a tool with real potential for initiating and encouraging on-going professional dialogue between the associate and student. In my view, the requirements within the CoRe structure to:

- determine and justify key content ideas for learning;
- identify students' prior learning, common misconceptions and/or learning difficulties and contextual factors that may impact on the learning;
- determine future learning; and
- devise appropriate instructional and assessment strategies

could help to draw out and highlight key PCK components for both parties in this partnership. I envisaged that the evolving CoRe had the potential to serve a number of purposes during the planning phase, such as providing:

- a scaffold for student teachers to start developing their emergent PCK;
- a prompt for associate teachers to identify and verbalise relevant components of their own professional knowledge; and as
- an early opportunity for student teachers to access the knowledge of their experienced associates.

In addition, I considered that the CoRes constructed in the planning phase might continue as a focus for discussion and provide points of reference in the expert-apprentice relationship as the student teachers start testing their emergent PCK with real students in classrooms under the guidance of their associates – something not possible in my university course. I hoped the CoRe would stimulate associate and student teachers to discuss pedagogical issues related to a specific topic as they arise during and after teaching. By providing on-going credible feedback, advice and feedforward comments stemming from the draft CoRe content and their own professional knowledge, the associate teachers could help the student teachers to develop expertise as new teachers more effectively.

This study involved six student teachers, but only four were able to engage in professional dialogue with their associate teachers about teaching and learning as depicted in a CoRe. These four student teachers Kay, Alan, Sam and Carl (pseudonyms) had varied backgrounds. Kay and Alan were fresh from university, having just completed science degrees, while Sam and Carl were older students with university degrees and extensive science-related work experience. Carl had also taught science students in a local high school for five years and was gaining his formal teaching qualification at the time of this study while still teaching. Kay was posted to a large co-educational city school for her practicum with a female associate teacher, and Alan to a similar neighbouring school with a male associate. Sam and Carl had been posted to the boys' school where Carl was currently teaching, and they both worked with the same associate teacher.

(Note: I was very fortunate to have Associate Professor Amanda Berry from Monash University, who was one of the co-founders of CoRes, interview the student teachers after their teaching practices. Her questions and/or comments are in bold in the following excerpts from the interview transcripts and the student teachers' responses are in plain text.)

The student teachers experienced different working norms for teaching and learning which were the consequences of decisions related to the choice of teaching topic, class levels, timing allocations, and pedagogical approaches. The degree and nature of the input of the associate teacher also differed according to the degree of interest of the associates and confidence of the student teachers in tackling the task. As the following accounts of the student teachers' teaching practices reveal, one student experienced involvement of the associate teacher before and during practicum in all stages of CoRe design, implementation (planning and teaching of the topic) and evaluation. In another case the associate was most active at the front end of the process, providing his two student teachers with feedback on CoRe design and suggestions to aid planning for teaching of the topic. In contrast, the associate teacher in the third case gave fairly directive input into the planning and teaching of the chosen topic, before the student teacher designed his CoRe. This last case, involving Alan, is an interesting place to begin discussion of the findings because the CoRe design activity unfolded in a way I had not anticipated.

### ***Alan's practicum experience***

Alan was unable to establish with certainty which chemistry topic and class he was expected to teach prior to practicum, so he found himself teaching the topic before he had tackled the CoRe construction. Thus, he had little idea of the key content students needed to learn or what might be appropriate pedagogy for that content. However, consultation with his associate during the teaching helped Alan get started with the 'big ideas' of his CoRe design and with aspects of the pedagogical approach he adopted, such as the use of real-life scenarios. In a group interview with his fellow student teachers, Alan revealed how this contribution and direction from his associate helped to shape components of his emerging PCK, notably knowledge of *curriculum* and knowledge of *instructional strategies*.

**So, Alan, what happened for you? Did you have somebody to help you?**<sup>1</sup>

I went over it with my associate teacher but ...

**Did you already have something down first or ...?**

I had started teaching it before I actually started the big ideas so ... I pretty much did it by myself but I had to talk to him a lot about the style that we were teaching it in because I went straight to the theory, it's just kind of the basics kind of thing, but he wanted to bring a whole lot of real-world scenarios in there. So I didn't know those because

he was a really experienced teacher and we just managed to work it out and then from there I got, like, the gist of the unit and then I could start creating those big ideas.

**Ok, so you kind of got a sense of them retrospectively?**

Yeah.

(Alan, group interview)

### Sam's and Carl's practicum experiences

As previously mentioned, Sam and Carl were on practicum at the school where Carl taught. They shared the same associate teacher (Carl's head of department) and teaching topics, but were teaching at different levels and to different curricula/qualifications (the Cambridge International General Certificate of Secondary Education [IGCSE] from the UK and the National Certificate of Educational Achievement [NCEA] from New Zealand). Collaboration occurred, as both students worked together first, and then as individuals with their associate. Here Carl talks about the value of this experience.

... we did CoRes for different classrooms, for different curriculums, if you like, because I'm teaching the Cambridge curriculum.

**Ok, right, so that's a British model?**

Yeah, yeah, IGCSE, just for this one particular class that I'm teaching this year. So I did a CoRe for that particular class before we taught ... I did it on Organic Chemistry. So Sam was also doing Organic Chemistry but for an NCEA class so he and I did talk about it ... I did my CoRe independently on my own; it turned out to be reasonably similar to the one that Sam did, I mean there's essential differences and things but we did independently of each other we came up with quite similar ideas, which was interesting. In the case of my CoRe, I then showed it to our associate, and he was fine with it; I mean, he's incredibly supportive of me and always has been ... so he gave it a good going over and he came up with a couple of ideas.

(Carl, group interview)

However, Carl could not test his emerging PCK as depicted in his CoRe.

I then went on to teach this but unfortunately ... because of the time constraints and because this was the first time we'd ever taught this particular British curriculum before, we discovered we'd run out of time ... what I tried to do was try and write this CoRe with a real emphasis on trying to get an enquiry-based learning and student-centred

stuff more incorporated into what we've done in the past. But in the end it didn't work out like that, I couldn't teach it like, I had to teach it the old way, which is really transmissive and not very satisfactory ... yeah, not ideal but we got the information through to them and they're sitting the exam as we speak, early next week.

(Carl, group interview)

Thus, Carl was unable to translate his newly acquired beliefs about the value of inquiry-based, student-centred learning (*orientations towards teaching and learning*), which underpinned his CoRe, to the reality of classroom teaching. He perceived that the external qualification's requirements restricted the testing and development of his emerging pedagogies to transmissive approaches, which were not aligned with the *instructional strategies* he had developed and outlined in his CoRe. It seemed other components of his emerging PCK (*assessment and students' understanding of science*) were also being moulded by these contextual circumstances where the focus had to be on the requirements of formal summative assessment and the imparting of information, and seemingly little opportunity was available to gain knowledge of students' learning progress through ongoing formative assessment.

Sam was unable to attend the focus group interview but in his written report he commented on how his CoRe facilitated discussion with his associate teacher. These interactions allowed him to plug gaps in his content knowledge (*knowledge of curriculum*); to appreciate the influence of external assessment on the classroom curriculum (*knowledge of assessment*); and what aspects of learning the topic students found difficult (*knowledge of students' understanding of science*) and how to address them (*knowledge of instructional strategies*).

Production and discussion of the CoRe meant any gaps in my personal content knowledge could be identified and addressed prior to commencing the unit. With this CoRe being based on an Achievement Standard [a component of the NCEA qualification] being introduced as part of the 2011 alignment [changes to the achievement standards] it was particularly useful as a means of identifying what changes had been made and how it would effect the teaching of the unit ... the CoRe provided a point of discussion with respect to timing and the order with which ideas are taught. My associate was able to ask in what order I would teach the key ideas portrayed in the CoRe and explain any suggestions based on his experiences with students and what aspects they found particularly difficult.

(Sam, reflection report)

### **Kay's practicum experience**

The fourth teacher, Kay, was able to meet and talk with her associate teacher during all phases of the practicum experience. Kay was most appreciative of the opportunity to receive evaluative comment on her CoRe from an interested and knowledgeable associate teacher well ahead of the teaching time, including suggestions for strengthening aspects of her emerging PCK.

[the course lecturer] made that quite easy for us, she wrote a letter to each classroom teacher explaining how - and sent them an article about CoRes [...]. And so, like, for me, my associate teacher, she gets very excited about anything to do with chemistry, especially new ways of doing things. That was good because I was very lucky to have someone who was that keen and she read the letter and the article and I sort of went in because I taught mine right at the end so I did this all beforehand and it was quite nice because I got to go away and do the ideas and stuff myself and then take it back to her at times to get her thoughts and experience, because I had the time to ... yeah, so mine was actually quite pre-planned.

(Kay, group interview)

Working in an iterative way with her associate, Kay was able to make adjustments to her CoRe to refine her content knowledge (*curriculum knowledge*), which in turn informed her planning as she made decisions about the content of upcoming teaching episodes.

I mean, after the discussion we decided to cut out this idea altogether because we decided this is all year thirteen [content for the year level above Year 12], not year twelve.

#### **So this is one whole big idea column that you decided to do that?**

The bits in here that applied to year twelve, they could easily fit into other big ideas. So instead of trying to have a tiny idea, it made more sense just to have four big ideas, big, big ideas, and so that was ... it made some things a lot nicer after having cut this whole idea out. I mean ... and so I read this again before teaching it, and this is ... not just before teaching, it was while I was planning my lessons and having a look at the unit as well, sort of justify when I'm teaching it.

(Kay, group interview)

Kay was also able to watch her associate teach the class at the beginning of the unit, which provided important insights into the learning characteristics

of students. Unlike her own ease with the content, she was surprised that the students did not find some chemistry ideas easy to learn, and she realised how little she had known about the learning difficulties that students can encounter and the reasons why (*knowledge of students' understanding of science*).

The other thing it helped me think about was the content was hard, but when it came to teaching it I was pretty clueless, things like difficulties, what students found difficult because to me this wasn't an overly difficult concept [but] knowing what students thought was really difficult, was really hard for me.

#### **So how did you figure that out?**

A lot of ... you know, after I've established relationships with students part of this my associate teacher taught and watching them - just watching, talking, having conversations with students really helped a lot of areas and the reasons why they found things difficult, some of them couldn't visualise in 3D. Some had trouble visualising without seeing a picture as well, some people really couldn't ... they knew what they were thinking about but they couldn't write it down using the correct terminology.

(Kay, group interview)

A 'working document' that Kay shared with her fellow student teachers at the group interview revealed that the associate teacher had been an active participant in this process of PCK development. This document was a copy of her original word-processed CoRe but with handwritten comments and/or changes made before, during and after teaching of the unit in different coloured pens and pencils by her associate and herself. The additions were clear evidence that Kay had refined her emerging PCK as she tested, evaluated and modified her initial PCK in collaboration with her associate teacher.

... after I had done this [the first CoRe] I went back to my associate teacher and she put in her thoughts in the blue pen ... My associate teacher as well, she liked to work from paper and I found it easier to work if I had it in front of me because my laptop is absolutely tiny so that was just sort of my way of personally doing it, I like to have it in front of me on paper.

#### **So your kind of styles and your format also worked together pretty well.**

Yeah, that was just sort of my preference and my associate teacher, she wanted to monitor how I was doing as well. She wanted to see how this

was built because I think she was quite curious about the process so I think that's another reason why she wanted me to ... every time I did one of these she had a look. I did this back when I was at university, emailed her my final copy and she's had a look at that too. It was just good because it's good to have someone really supportive, like she wanted - she wasn't telling me how to do it but she was giving me her experience and just that support, which was really, really quite good ...

(Kay, group interview)

## Student teachers' perceptions of the collaborative CoRe design task

All four student teachers who were able to engage in the CoRe design task with their associate teachers reported positive collaborative experiences that enhanced their professional learning, despite the differences in each case. One aspect of the associate teachers' involvement that drew particular appreciation from the student teachers was the interest the associate teachers showed in the CoRe task and their preparedness to spend time critiquing and sharing their expertise with them to maximize the benefits of their practicum teaching.

That was good because I was very lucky to have someone who was that keen ... because I got to go away and do the ideas and stuff myself and then take it back to her at times to get her thoughts and experience ...

(Kay, focus group interview)

Carl appreciated how his associate teacher voiced and demonstrated vocational responsibility for his professional development as a student teacher during practicum.

... he's a great believer in encouraging student teachers to develop ... he's incredibly supportive of me, so he gave it a great going over and he came up with a couple of ideas.

(Carl, focus group interview)

Those student teachers who were able to pre-prepare CoRes felt the research and thought they put into their draft CoRes informed their emerging PCK in chemistry, particularly curriculum components, and gave them sufficient background to engage meaningfully and confidently in discussions with their associates to advance their PCK. The CoRe itself provided common ground for discussion and a platform from which to continue developing their PCK.

I had acquired the necessary content and curriculum knowledge to teach this unit. Without analysing this material I would not have known what

specifically was to be taught in this unit, so at least when discussing the CoRe with my associate we were on the same page. This meant that we could spend time discussing specific misconceptions and learning activities that could be used to identify and address these.

(Sam, reflection report)

Professional discussions with associates around the CoRes provided the student teachers with insights into teaching and raised their awareness of pedagogical issues related to the topic. They came to appreciate the expertise and mentoring of their associates and the currency of their knowledge.

Things like electronegativity here [pointing to her CoRe] 'cause it's stuff I didn't quite realise was going to be in there and then she [her associate] was linking it to all these other ideas I hadn't thought of.

(Kay, focus group interview)

This observation from Kay's final reflection report sums up the general feeling of the four student teachers who engaged in CoRe construction with their colleagues.

Overall I found developing my CoRe before teaching it and alongside experienced teachers – some of whom [as student teachers in their pre-service training] had developed their own CoRes (in different topics) very helpful as I was given a range of perspectives and ideas to consider and incorporate as I saw useful to apply to the particular class I was teaching to. I felt as though these discussions help develop my skills and knowledge in areas such as knowledge of learners and their characteristics (especially in areas they find difficult to grasp the concepts or content), as well as knowledge of content (through a lot of talking about the particular content I was teaching and through developing teaching schemes and resources).

(Kay, reflection report)

It is important to note that the two student teachers, Sally and Doug (pseudonyms), received little if any input from their associate teachers into their CoRe design, citing apparent lack of interest and/or time on the part of their associates as possible reasons.

I got very much the idea that it [the information sheet about the CoRe exercise from the course lecturer] got put aside ... I don't know what her reaction was, I didn't get to see any of it, I was lucky if I got five minutes of her time in a week.

(Sally, focus group interview)

Sally had the added difficulty of having to withdraw from the practicum early owing to health problems. She had partially developed her CoRe, but had not been able to show it to her associate and have a conversation about it. Her associate was also reluctant to let Sally teach the class, so her emerging PCK was largely untested.

One of those ... very protective of this class. So ... yeah, a lot of mine is quite untested and untried because I haven't had the chance for that ... between yeah, cutting practicum short and not having that discussion and not being let near that class much.

(Sally, focus group interview)

Unfortunately Doug's associate teacher was openly dismissive of the CoRe task.

I gave it to him and he read the letter and then screwed the letter and [threw] the article into the bin in front of me.

(Doug, focus group interview)

Early in his practicum, Doug was disturbed by the students' seeming lack of interest in the qualitative chemistry being taught by his associate teacher and their lack of learning, so "as a consequence of this I chose qualitative chemistry as my topic. I started with the premise that students needed to be interested in the topic and it needed to be current" (Doug, reflection report). So without the involvement of his associate teacher Doug designed his CoRe and subsequently planned and taught the unit. However, he was unable to achieve the pedagogical outcomes he had hoped for.

I had to sit down and do it myself and I fell into some traps along the way and at the end of it I looked back on it and looking back on it now I see I fell into a relatively common trap for teachers doing an assessment – because my big ideas came from the assessment documents it means that I taught to that assessment rather than teaching to the topic.

(Doug, focus group interview)

Whether input from his associate teacher would have changed this outcome can only be speculated upon.

## Conclusions and implications

While the four student teachers who established working relationships with their associate teachers operated under different contextual conditions, all spoke positively of the insights collaborative CoRe design gave them into classroom teaching and learning and of the outcomes in relation to their emerg-

ing PCK. Thus, from the perspective of these student teachers, the findings from this small study do suggest that CoRe design was a successful mediational tool in helping them to begin moving from the community of novice teachers towards the community of experienced expert teachers. They valued their associate teachers' interest in collaborative CoRe design and preparedness to share their expertise; the use of CoRes as a focus for authentic professional discussion with their associate teachers; and the enhancement of their emerging PCK through associate teacher input into CoRe design.

It was clear from this study that the associate teachers' willingness to participate in innovations of this type was a major factor in achieving the outcome of enhanced PCK development for the student teachers. These associates had in common qualities of pedagogical curiosity and vocational responsibility for the development of novice teachers, which underpinned their mentoring effectiveness. Student teachers of associates who did not display these dispositions appeared disadvantaged in terms of their PCK development. The CoRe design task gave the interested and involved associates the opportunity to engage in the deeper aspects of modelling and mentoring through purposeful pedagogical discussion. Issues, such as the rationale for curriculum design decisions which are so often missing in the practicum experience for expert teachers and student teachers (Sanders *et al.*, 2005) could be discussed during processes of critical reflection.

One aspect of professional collaborations of this type that warrants further research is the potential for student teachers to be agents of change when on practicum. Associate teachers' curiosity about the process of CoRe design in this study is a strong indication of their openness to innovation in professional learning, and involvement in pre-service teacher education may be a means for introducing new approaches. There were signs that associate teachers in this study were interested in picking up on the CoRe idea as they could see possibilities for programme design and evaluation in their own departments. Planned and purposeful involvement of associate teachers with student teachers, using mediational tools such as CoRe design, could have the added advantage of prompting and facilitating teacher change within the profession.

## References

- Fairbanks, C.M., Freedman, D., & Kahn, C. (2000). The role of effective mentors in learning to teach. *Journal of Teacher Education*, 51, 2, 102-112.
- Fazio, X., Melville, W., & Bartley, A. (2010). The problematic nature of the practicum: A key determinant of

- pre-service teachers' emerging inquiry-based science practices. *Journal of Science Teacher Education*, 21, 665-681.
- Girod, M., & Girod, G. (2006). Exploring the efficacy of the Cook School District simulation. *Journal of Teacher Education*, 57, 5, 481-497.
- Hume, A. (2010). CoRes as tools for promoting pedagogical content knowledge (PCK) of novice chemistry teachers. *ChemEd NZ*, 119, 13-19.
- Loughran, J., Mullhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, 41, 4, 370-391.
- Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education. *International Journal of Science education*, 30, 10, 1301-1320.
- Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome N.G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Boston:Kluwer.
- Putnam, R.T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29, 1, 4-15.
- Sadler, T. (2006). "I won't last three weeks": Preservice science teachers reflect on their student teaching-teaching experiences. *Journal of Science Teacher Education*, 17, 217-241.
- Sanders, M., Dowson, M., & Sinclair, C. (2005). What do associate teachers do anyway? A comparison of theoretical conceptualizations in the literature and observed practices in the field. *Teachers College Record*, 107, 4, 706-738
- Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1, 1-22