From Scientist to Science Teacher:

A Career Change Teacher in Transition

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Abstract: *One method of addressing the shortage of science and mathematics teachers is to train scientists and other science-related professionals to become teachers. Advocates argue that these career changers as discipline experts can relate the subject matter knowledge to various contexts and applications. In this paper, through interviews with a former scientist and her students, we examine how one career changer used her expertise in microbiology to teach microscopy. These interviews provided the basis for a description of the teacher's instruction which was then analysed for components of domain knowledge for teaching. Consistent with the literature, the findings revealed that this career changer needed to develop her pedagogical knowledge. However, an interesting finding was that the teacher's subject matter as a science teacher differed substantively from her knowledge as a scientist. This finding challenges the assumption that subject matter is transferable across professions and provides insight into how to better support career changers to transition from scientist to science teacher.*
Keywords: STEM, science teaching, scientist, subject matter knowledge, contextual knowledge

1. Introduction

A persuasive argument for encouraging scientists and science-related professionals to change careers and become teachers of Science, Technology, Engineering and/or Mathematics (STEM) is that they bring to the classroom (a) advanced subject matter knowledge and (b) knowledge of STEM in the real world. This viewpoint is endorsed by career changers themselves. For example, Abi — a former scientist — perceived herself to have substantial capability in both *content* and *contextual* knowledge compared to her teacher colleagues.

Content knowledge is no issue …Just comparing myself to some of the teachers that haven't got that background [scientist] ... I think I have a broader view [context], like I think sometimes I'm able to see things from much further back so they're [other teachers] right up at the front of the particular detail maybe of the subject that they're covering … but I think I have a perception of context … I can see that there's so much I can use to provide context for my kids.

Given the strong impetus to retrain scientists as science teachers, we investigate the question, "*How does a teacher with advanced subject knowledge apply this knowledge in instruction?"*

2. Background

2.1. Subject Matter Knowledge and Career Change Teachers

Mounting research has confirmed the importance of quality teaching in maximising student achievement (e.g., Hattie, 2009; Rivkin, Hanushek & Kain, 2005; Rockoff, 2004). However, defining the attributes of quality teachers is somewhat problematic. The relative importance of a teacher's own subject matter knowledge of what they teach, their teacher preparation program, their personality and their dispositions toward teaching are all hotly debated (Berry, Daughtrey, & Wiede, 2009). However, subject matter knowledge plays a significant role. Teachers who have deep knowledge of their subject tend to focus on systems and underlying concepts and are effective in implementing inquiry approaches to learning. Teachers with a superficial subject matter knowledge focus more on isolated concepts and adopt more transmissive approaches in teaching and have less effective capabilities to implement engaging inquiry oriented lessons (e.g. Roehrig & Luft, 2004; Trigwell, 2011).

2.2. Our Use of Mathematics Research Approaches to Investigate Science Teaching

Mindful of the interrelationship among STEM disciplines to broaden understanding, we depart from traditional subject lines in our investigation and appropriate two productive lines of inquiry from mathematics education research to investigate a career change science teacher. First, notwithstanding the validity of Abi's views of her science teaching, we include her students' viewpoints. Building on the work of Freudenthal, van den Heuvel-Panhuizen (2008) argues that students can provide insight into the effectiveness of instruction from their vantage point as experienced learners. She uses the term "didactikids" to refer to students when they are undertaking the role of reflective commentators on their education. Second, we draw on the work of Ball and colleagues (e.g., Ball, Thames, & Phelps, 2008; Hill, Ball, & Schilling, 2008), who, over many years, have investigated the knowledge required for mathematics teaching. Our stance is underpinned by Rutherford and Ahlgren (1990)'s view that "Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analysing data".

3. Design and Methods

This study was part of a longitudinal study of 13 beginning STEM teachers who possessed advanced qualifications or industry experience prior to becoming teachers. In Year 1, an initial interview with teachers sought relevant personal and demographic data. Two further semi structured interviews were conducted using a protocol adapted from the literature (Luft & Roehrig, 2007). One interview was conducted six months into the teaching year. A further day-long debriefing interview was conducted a couple of weeks after the completion of a topic in which approximately 5 hours of lessons had been videotaped. The taping of a topic and the day-long debriefing interviews were repeated in Years 2 and 3. Focus group interviews were conducted with students after the completion of each topic. Field notes were also recorded of the school environment and resources (Lawrence & Green, 1995).

The source data for this study were interviews with Abi and her Year 8 students in the first year of the larger study from a unit of work on microbiology. These data were selected for analysis because Abi's professional expertise is in microbiology. We commence by presenting Abi's perspective and that of her students. We then analyse Abi's teaching knowledge through components of Hill et al.'s (2008) Domain map of knowledge for teaching (Figure 1), which is discussed shortly.

4. Results

How does a teacher with advanced subject knowledge apply this knowledge in instruction?

Abi spoke explicitly about how she was able to apply her content knowledge to various contexts. For example, in an interview, she gave the example of how her knowledge of microscopy supported learning through the narratives she was able to use with particular science topics.

> We've just started doing microscopes with the Grade 8s in the unit so we're doing sort of life under the microscope and I'd collected a bunch of images for them … Whereas I sort of talked to my kids more about the significance of microscopy and different things that it can be used for which I think maybe the other teachers, you know they had that narrow perspective that microscopes allow us to look at things at that small detail. (Abi, 2009)

However, Abi acknowledged that her ability to use stories in teaching science varied with the topic. Whereas she had stories for microscopy, she lacked stories for earth science.

> I find some topic[s] easier to do that, like the microscope one that we were doing today … I simply have those stories, they're just more accessible. …I have all the connections as well [for microbiology] but with something like — I

know Earth science is something I'm shocking at ... it wasn't as obvious what I should tell them beyond just the flat definitions for them. (Abi, 2009)

Stories were clearly an important tool in Abi's repertoire and she compared her ability to identify suitable stories as "light bulb" moments similar to when students grasp a concept. "The kids are having their light bulb moment when they actually grab hold of the concept, but I'm having my own little light bulb moment and so I'm going that story really worked with the kids." (Abi, 2009)

Abi also spoke about how she was able to supplement the core curriculum from her own experience. For microscopy, she added additional slides and photographs.

Whereas I actually ended up talking to my kids about you know we looked at some cancer cells that were done using fluorescent microscopy. We looked at lots of different images like biological, like ecological field studies, where they were looking at animal structures and just did that breadth. (Abi, 2009)

Today I was explaining to them we did an exercise with the microscope, like I actually put up all these different pictures of different things and...I asked them which one of these is a micrograph of an artery... asking them what...which one they thought was an artery so I had 6 photos up and I had deliberately selected things that you might mistake for an artery so I had a cross section of a grape you know of a thick edge and then it had its cells in the middle so it would look a bit (like a vein) (Abi, 2009)

However, the success of Abi's approach was not evident. She commented that one of the students misinterpreted the slide of the grape as the slide of a vein apparently as she intended. Her pedagogical purpose appeared to relate to encouraging students to reason about the slides but the task itself was problematic as they could not reason successfully and she ultimately gave them the answer.

And one of the kids did exactly what I thought they would do and it was stained sort of blue around the outside and pink in the middle so they'd obviously …, I was like "Joe (pseudonym) why do you think that's it?" And he said, "It's red and white Miss you know because there's red cells in the middle and blue around the outside so that's a bit like vein" … Even though I knew I was about to tell him he was wrong, I compliment (sic) them on their reasoning so I said to Joe, "Excellent you're using what you know about blood and you're trying to work this out". And then when I came back to it and I gave them the answer. (Abi, 2009)

Although it is accepted pedagogical practice to problematise tasks to elevate the level of challenge, the tasks should be achievable by the students with the teacher's support. Resorting to supplying the answer suggests that there was no logical way for students to be successful.

Although Abi's questionable pedagogical approach using the grape could be explained by her novice teacher status, it is less easy to explain why with her professional knowledge she engaged her students in a pointless task. When asked what the students did at the end of a microscope lesson, Abi explained they had the task of finding organisms in pond water.

A[1]: (One task) was to look at the sample under the microscope and see if they could find an organism … The pond water that we have has several different organisms in it from small fish to worms, nematodes, all sorts of stuff.

I: Now there was a problem wasn't there, that there was no organisms in the water — because of the rain?

A: This was a bit of a disaster when I got them to do the research.

Abi's lack of forethought in asking the students to examine pond water diluted with fresh rainwater to identify organisms appears a basic oversight for a professional microbiologist. Hence, like the grape task, the pond task lacked opportunity for applying knowledge of microscopy.

Although Abi spoke at length about microscopy in her interview, and the content and context, only a few students commented about their microscope lessons. Their learning had two aspects. The practical use of the microscope as a tool

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[1] A represents Abi; I represents the Interviewer.

was referred to by two students at quite basic levels: “I learnt that if you put your eye to a microscope it hurts.” and “Just really looking in the microscopes, looking at the different levels (magnifications).”
There was also the knowledge of cells and the practical element of staining cells with student interest piqued due to the practical tasks.

> My favourite thing was when we got to look at all the different cells and see what's inside them and that, and my group we saw two cells splitting apart.
>
> The best part was dyeing (staining) the cells and looking at what cells through the microscope and looking how detailed they were.
>
> (We learnt about) the structure of cells and what happens in the cells.
>
> The prac we did was pretty cool because we were using microscopes to look at cells and it taught us not only how to use microscopes but seeing all the cells was pretty cool and yeah, they all looked amazing.

Taking on the role of ‘didactikids’, Abi’s students had suggestions to improve her teaching about microscopy referring to explanations, use of technology and specialty microscopes.

> She could have maybe explained how to use the microscopes a little better.
>
> She could have used a microscope that she could put up onto the big screen so that we could all see it better, and then we could all know what she's looking at and she could describe it to us and stuff.
>
> Use different types of microscopes, like electron microscopes and that to help see it differently and see further.

As Abi had advanced knowledge of microscopy, their suggestions have merit. Two students also mentioned another content issue at a more general level relating to how she taught students who were already competent at the year level work.

> The only problem is that she doesn’t let anyone do the work before (independently), instead she just explains everything to everyone even when people know what to do.
>
> I think she should teach other stuff to people who already know the stuff. Say, if we all already know the stuff in Year 8 science she should try to teach us some Year Nine stuff, or Year 10, and to improve our knowledge.

The ability to advance students is often restricted by a teacher’s knowledge base — a situation not relevant to Abi. However, she failed to recognise those students capable of more advanced work.

5. Discussion

Abi commenced her teaching career with an assumed advantage of expert science content knowledge together with knowledge of applications of her knowledge. However, this knowledge does not seem to have advantaged her students to a great extent. Her difficulties can be explained by gaps or shortcomings in the domain map of her science knowledge for teaching (Hill et al., 2008). According to Hill et al., knowledge for teaching in a particular domain requires (a) subject matter knowledge and (b) pedagogical content knowledge (Figure 1). Thus, a new teacher with advanced subject matter knowledge should have a wealth of subject matter knowledge but be a pedagogical novice. Hill et al.’s (2008) domain map of knowledge for teaching developed in mathematics provides the means to test this assumption.

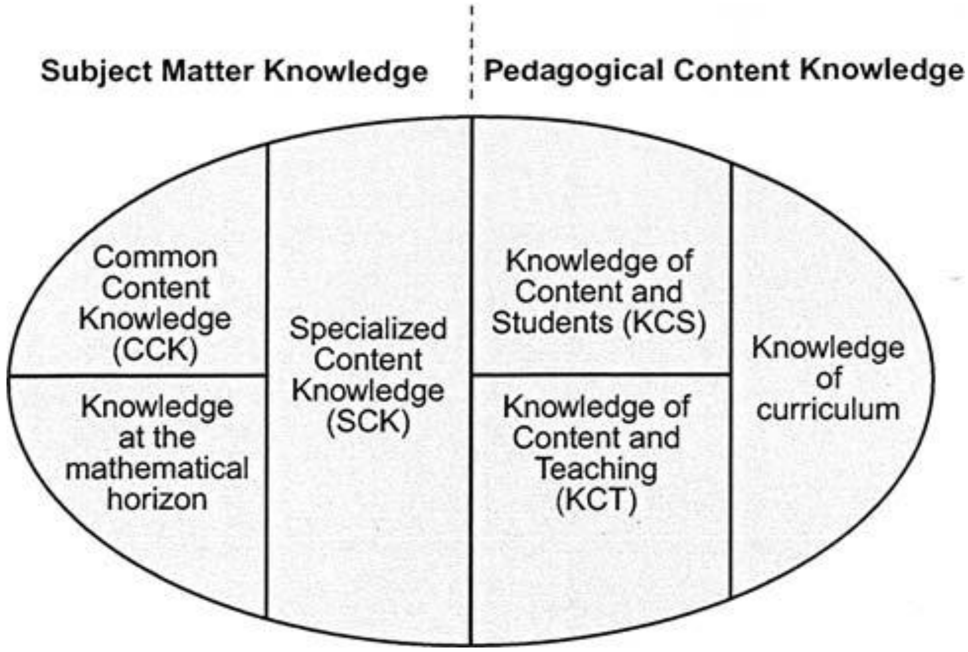

Figure 1. Domain map for mathematical knowledge for teaching (Hill et al, 2008, p. 377).

Abi's pedagogical knowledge, like that of many novice teachers, still needs to develop. Presumably, her *knowledge of the curriculum* will become more familiar over time. However, in addition to the curriculum, she needs to develop *knowledge of content and students* (KCS) and *knowledge of content and teaching* (KCT). At present, Abi seems to lack KCS, with her students commenting that she provided too much information about how to do a task, when some students did not require this information. She also failed to recognise students' proficiency in the tasks she set. Abi also needs to develop KCT. Engaging students in a task in which they searched for nonexistent organisms in pond water showed a lack of KCT. Each of these gaps in pedagogical knowledge is expected at least to some extent in a teacher who has changed careers from scientist to science teacher. However, typically, there are high expectations of the subject matter knowledge of these career change teachers.

Individuals entering teaching training programs with science degrees, particularly doctorates, are assumed to have advanced subject matter knowledge. However, Hill et al. posit that subject matter knowledge has two strands,

> *Common content knowledge* (CCK), roughly described as knowledge that is used in the work of teaching in common with how it is used in many other professions or occupations that also use mathematics, and *specialized content knowledge* (SCK), or the mathematical knowledge that allows teachers to engage in particular teaching tasks, including how to accurately represent mathematical ideas, provide mathematical explanations for common rules and problems, and examine unusual solutions methods to problems (pp. 377-378).

Applied to science teaching, Abi has CCK. However, she needs to further develop SCK because the specialised knowledge of a science teacher differs from that of a scientist. Ball et al. (2008) argue that there is a distinct difference between the work of mathematicians and that of mathematics teachers. They give the example of error analysis, which is part of the work of both mathematicians and mathematics teachers and argue that this work is done quite differently by each of these professionals:

> Although mathematicians engage in analyses of error, often of failed proofs, the analysis used to uncover a student error appears to be related to, but not the same as, other error analyses in the discipline. Furthermore, whereas teachers must process such analyses fluently, no demand exists for mathematicians to conduct their work quickly. (p. 397)

Applying this distinction to the work of a scientist and that of a science teacher, a plausible explanation for Abi's choice of a cross section of a grape on a microscope slide could be that for a scientist the grape slide illustrates a particular point, however this point was lost on the students and hence, their reasoning was misdirected. This distinction between the specialised knowledge of scientists and science teachers creates a conundrum because in order to be successful in teaching, to some extent, career change scientists will have to modify their identity to think like teachers. (For further discussion of the identity development of Abi and other career change teachers see Watters and Diezmann (2012)).

6. Conclusion

The arguments for training scientists to become science teachers are well intentioned. However, for career changers to be successful in the classroom, they need differential training that equips them to move fluidly between their familiar world of science and knowledgeable colleagues to the world of the classroom and less knowledgeable learners. For them, the classroom world is paradoxical because they have years of classroom experience as learners. However, in the transition from student to teacher, they need to appreciate that this familiar world is now unfamiliar territory. Hill et al's (2008) domain map highlights some of the unfamiliarities they will encounter and need to address for a successful transition. Wholistically, career change teachers, like Abi, need to transition from their roles as scientist to that of bricoleurs, a term coined by Lévi-Strauss (1962) to explain differences in types of knowledge. Reilly (2009) explains

> Instruction might well be understood as bricolage in that he (teacher) constructs opportunities that open spaces of possibility, not destined certainties. He understands the school year, not as a collection of units of study ready to be enacted, but rather as learning that is collaged and juxtaposed and made with students along the way. As such, he reuses strategies and texts, changing intention to match perceived need, pulling in materials he finds at hand as needed. (p. 383)

The goal for Abi and other career changers is to develop the mindset of the bricoleur for use in tandem with the subject matter knowledge of a teacher. However, the identity development of career change teachers is not straightforward and requires that teachers are able to develop a sense of autonomy and confidence as teachers within a supportive work environment (Watters & Diezmann, 2012).

Acknowledgements

This research was funded by the Australian Research Council DP0984349.

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