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Exploring pre-service science teachers' epistemic agency to develop their pedagogy for science teaching

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Introduction

According to the Collins English dictionary, science is defined as: “The systematic study of the nature and behaviour of the material and physical universe, based on observation, experiment, and measurement, and the formulation of laws to describe these facts in general terms”.¹ Scientists have established this body of scientific knowledge, but we say it is tentative because it can change as new discoveries are made which add to the body of knowledge. Thus, when learners engage in experimentation and measurement at school level, they are verifying the laws that scientists have already proven. For example, an investigation of the relationship between acceleration and the net force experienced by a body in motion would be a verification of one aspect of Newton's Second Law of motion. At best, the learners are acquiring

¹ <https://bit.ly/2UTGWGN>

Teacher Education for Transformative Agency

process skills in scientific investigation and should be able to formulate the law mathematically and in words. There are multiple ways in which the law can be represented that are appropriate to learners' needs (Ainsworth, 2008). There are many semiotic tools in language, algebraic systems, diagrams, etc. that are used for the appropriation of knowledge through representational activity (John-Steiner & Mahn, 1996).

My focus as a science teacher educator is to develop the pedagogical repertoire of pre-service science teachers in the Postgraduate Certificate in Education (PGCE) programme at university. This is underpinned by an epistemological question: How do the students come to know what they know in science? I proffer that they become enculturated into scientific discourse through interaction with experienced others who use the tools of established scientific practice. The students are graduates who have completed a minimum of three years specialising in Chemistry or Physics. This exposure to develop their disciplinary knowledge primarily occurs through engagement with the theory and practical work in the laboratory. Specialists in the discipline mediate these interactions, and as Rau (2017:724) stated: "These social interactions mediate students' engagement in both sense-making processes and inductive learning processes". Hordern (2015) also advanced the argument that, in teaching, improvements in educational outcomes can only be attained through sustained efforts by the professional community of teachers and teacher educators. This implies that there must be collaboration within a community of practice to realise these outcomes.

In this chapter, I argue that as a teacher educator in science education, my role is to introduce prospective science teachers into science-as-practice to develop them as epistemic agents in the classroom. I use sociocultural theory as a theoretical lens to understand how PGCE students develop their knowledge base for professional practice. As graduates, they have acquired the disciplinary knowledge in Physics and Chemistry, but appropriating the vertical discourse and recontextualising it for teaching is not an easy matter (Hordern, 2015). The prospective science teacher needs the pedagogical knowledge for teaching, which brings together the disciplinary discourses and the educational research that relates to pedagogy. In this respect, I outline how multiple representations are used as a pedagogic approach in the classroom to mediate scientific knowledge.

Sociocultural theory and science education

Leach and Scott (2003) posited that the goal of teaching is to introduce new ways of thinking and talking to students by showing how it is done in a particular context. They proposed that Vygotskian theory brings together the social plane and individual constructivism in regarding the student not as a *tabula rasa*, but as an active participant in the learning process. Students have to understand scientific knowledge and internalise it for their own personal use, and language plays an important role in mediating this knowledge. This sociocultural view of learning highlights the interdependence between the individual and social processes in learning and development (Scott & Palincsar, 2013).

Sociocultural theory shifts us away from transmission modes of pedagogy and opens up new possibilities for teaching and learning in the classroom (Daniels, 2001). The emphasis is on semiotic mediation as an explicit type to understand how higher mental processes function in the social world. Wertsch (2007) argued that Vygotsky emphasised qualitative transformation through the inclusion of signs and tools. He differentiates between implicit and explicit mediation as follows:

- ◀ Explicit mediation is when an overt and intentional stimulus is introduced into an activity, and the signs involved are obvious and non-transitory. The signs are usually designed by an external agent to help reorganise the activity.
- ◀ Implicit mediation is ephemeral, short-lived and less easily taken as an object of conscious reflection. It is not intentionally introduced into human action and becomes integrated with other forms of goal-directed behaviour. It “involves signs in the form of natural language that have evolved in the service of communication” (Wertsch, 2007: 185).

The zone of proximal development (ZPD) is a characteristic of sociocultural theory, and a notion extensively applied in education. It denotes the distance between what an individual could accomplish independently and in collaboration with others (Vygotsky, 1978:86). This has implications for the way in which a science lesson is designed and the facilitator role that the teacher can potentially play in the classroom to promote higher-order thinking. An example of this could be that learners are expected to observe what happens when water boils in a beaker. At a macroscopic level, they may state that steam is forming when the water boils. However, when they are challenged to explain this change of phase from a liquid to vapour, they may delve into the microscopic level and explain that heat increased the kinetic energy of the molecules, thereby causing the molecules at the surface to

Teacher Education for Transformative Agency

escape faster. This shows that in the absence of a prompt the learners would engage in surface learning rather than deep learning. It is also an example of scaffolding, which entails the novice being assisted by the experienced other in the social setting (Daniels, 2001). Depending on the level of education, what appears to be a simple explanation could evolve into something more complex when mathematical symbols and equations are introduced to represent the phase changes.

In science teacher education, the pedagogies that prospective science teachers appropriate are shaped within social settings. As Vygotsky (1978:55) stated: “The internalization of socially rooted and historically developed activities is the distinguishing feature of human psychology”. Van der Veer (2007) also suggested that the shaping of abilities takes place in a specific sociocultural context, and individuals make use of the ideas and tools that are available. This is particularly important in science teaching, as the goal should be to support students to engage in activities and use the tools consistent with the practices of the community (Scott & Palincsar, 2013).

It is these semiotic tools that are a feature of multiple representations in science education, and which are used for explicit mediation purposes. I now briefly outline how these multiple representations are used in science education.

Multiple representations as explicit mediation

Multiple representations refer to the practice of re-representing the same concept through different forms. They are artefacts that symbolize an idea or concept in science (Prain & Waldrip, 2006; Tang, Degado & Moje, 2014). These can take the form of analogies, verbal explanations, written texts, diagrams, graphs and simulations. Research has also shown that student-generated representations can enhance learning (Waldrip & Prain, 2012). However, if they fail to see the interrelationships between the multiple representations then it could hinder their learning (Rau, 2020).

Multiple representations also help to connect various aspects of a phenomenon to build a deeper understanding (Won, Yoon & Treagust, 2014). Figure 9.1 illustrates diagrammatically how water undergoes a phase change that includes the symbolic as well as textual description. The diagram also shows the microscopic level to elucidate that the molecules are increasingly further apart as the temperature increases. This ties in with the ZPD as discussed above – the teacher can explore the concept at varying levels of complexity. Students, therefore, need to be able to translate from one representation to

another and teachers should support such integration (Won et al., 2014:842). Moore et al. (2018) underscore this when they indicate that having a large repertoire of representations is inadequate unless teachers know how to scaffold students' ability to translate between representations.

Phase Change Diagram for Water (H_2O)

Figure 9.1 Phase changes of water

Kozma and Russell (2005) maintained that individuals use representational systems as they are integrated into communities of practice. This sociocultural perspective posits that representational competence is used to construct and communicate understanding. Again, this can be connected to the students' ZPD – those with little representational competence are likely to engage in surface learning while deep learning is more likely to occur when the student is able to navigate between different representations.

Rau (2017) also contended that when students acquire representational competence they become part of the science community of practice. It is through social interactions that they engage in disciplinary discourse which involves both verbal and non-verbal communication (Rau, 2017:724). In chemistry, for example, students have to visualise the formation of a chemical bond such as in the water molecule. This could be represented in various ways

Teacher Education for Transformative Agency

such as a Lewis diagram or a ball-and-stick model. Rau (2017:748) stated that different “representational competencies are a critical aspect of expert practices in chemistry”. It is therefore important that students acquire this competence to make sense of different concepts in chemistry, and thus become enculturated to participate in scientific discourse (Rau, 2020).

In the next section, I outline what is meant by science-as-practice as a goal for PGCE students to develop their epistemic agency in the classroom. This is contrasted with science as inquiry, which is also a commonly supported goal in science.

Science-as-practice versus science-as-inquiry

Osborne (2014) made a powerful argument for the development of students’ understanding of the epistemic basis of science – how we know what we know – by engaging them in the common practices of science. This contrasts with the dominant focus of science as inquiry that has been advanced by various curricula, particularly the National Science Education Standards (National Research Council, 1996) in the United States. Science-as-inquiry promoted the development of process skills associated with doing scientific investigations or practical work. Various studies reported the positive effects that inquiry-oriented science learning and teaching have on pre-service teachers’ understanding of the nature of science, attitudes and beliefs about science learning and teaching, and their classroom teaching performance (Haefner & Zembal-Saul, 2004; Liang & Richardson, 2009). A Google Scholar search on process skills in science yields over five million hits in under one second. It is clear that there is no shortage of research on the topic and the research cited here is but a drop in the ocean. Research over the last twenty years has therefore strongly advocated for science-as-inquiry as the dominant pedagogical approach in the classroom.

Erduran and Dagher (2014) stated that school science has been dominated by an emphasis on teaching scientific processes with a focus on process skills. However, they argued that this fails to address how school science fits into wider scientific practices, which situate science into epistemic practices to develop scientific knowledge. This highlights the importance of scientific practices that are embedded in social and cultural practices, and consequently promotes the acquisition of epistemic knowledge in science. The National Research Council (2012:50-53) elaborated on scientific practices as follows:

Exploring pre-service science teachers' epistemic agency to develop their pedagogy for science teaching

- ◀ The scientist has to formulate empirically answerable questions about phenomena, establish what is already known, and determine what questions have yet to be satisfactorily answered.
- ◀ Scientists construct and use a wide variety of models and simulations to help develop explanations about natural phenomena.
- ◀ Scientists plan and carry out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables.
- ◀ Scientists use a range of tools, including tabulation, graphical interpretation, visualisation and statistical analysis, to identify the significant features and patterns in the data.
- ◀ Mathematics and computation are used for a range of tasks, such as constructing simulations, statistically analysing data and recognising, expressing and applying quantitative relationships.
- ◀ The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.
- ◀ Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.
- ◀ A major practice of science is the communication of ideas and the results of inquiry: orally, in writing, with the use of tables, diagrams, graphs and equations, and by engaging in extended discussions with scientific peers.

It is also evident from these aspects of science-as-practice that most of them are associated with multiple representations. Scientists communicate their findings in various forms for their peers to validate the data and establish its reliability. The use of models, textual explanations, symbolic and graphical representations all form part of multiple representations.

Osborne (2014) argued that epistemic knowledge is a necessity in science and it comprises two components: (a) Knowledge of the constructs and defining features essential to the process of knowledge-building in science, and (b) The role of these constructs in justifying the knowledge produced by science. The manner in which scientific practices are advanced is directly related to the epistemic frames adopted in the classroom. The next section outlines this construct.

Students' epistemic framing

Framing is the process of making sense of what is occurring in a particular social activity. It is useful in the teaching and learning context because students can participate while teachers create the context (Campbell & Fazio, 2018). Shaffer (2006:228) proposed that:

Epistemic frames are a form of knowing *with* that comprise, for a particular community, knowing *where* to begin looking and asking questions, knowing *what* constitutes appropriate evidence to consider or information to assess, knowing *how* to go about gathering that evidence, and knowing *when* to draw a conclusion and/or move on to a different issue.

These epistemic frames are also associated with particular communities of practice and serve as the organising principle for practice. In the science classroom, students seldom get an opportunity to assess the evidence to make sense of a concept. This approach to knowledge building in the classroom ties in with the focus of scientific practices to develop the epistemic knowledge of the prospective science teacher. It also emphasises the importance of scaffolding as the teacher provides the prompts to allow the student to operate in the ZPD and promotes higher-order thinking.

Sin (2014) suggested that the relationship between pedagogy and how epistemology informs (or can inform) learning and teaching in Physics has been neglected. The author argued that if this was done it would harmonise “learning and teaching in physics with the nature of knowledge and the process of knowledge creation characteristic of the discipline with a view to enhancing student learning” (343). The prevalence of constructivism promotes an active engagement of the learner with the environment in order to gain conceptual understanding. At an undergraduate level there is, however, a disjuncture between the social constructivist practices of professional physicists and classroom pedagogy, which is generally informed by positivist epistemology. Scientists socially construct knowledge by engaging in research in the laboratory, whereas science is presented as facts and laws in the classroom. Students are expected to imbibe this knowledge in a systematic fashion, which contradicts the general messiness of knowledge making. It is these positivist-teaching approaches that “conceal the epistemic properties of scientific practice” (Sin, 2014:353).

Schuster et al. (2018) used two epistemic approaches to develop students' conceptual understanding of core ideas in science. In the one approach, “the core concepts and principles are presented and explained by the instructor as established science knowledge, while in the other the core ideas are co-

Exploring pre-service science teachers' epistemic agency to develop their pedagogy for science teaching

developed by students and instructor in guided-inquiry fashion" (391). On the one hand science is presented as an established body of immutable knowledge which the teacher directs; whereas the other approach "casts learning as science-in-the-making, and aims to reflect not only what we know but how we come to know it" (Schuster, 2018:392). The point is made that the approaches do not differ because the one promotes passivity and the other active engagement; rather, both are learning-centred involving the student and teacher alike. The interesting conclusion of the study was that the two contrasting epistemic modes yielded similar learning gains for either approach.

Stroupe (2014:488) argued that: "Reframing students' learning expectations around legitimate participation in science-as-practice requires that they take on a new role as *epistemic agents*—individuals or groups who take, or are granted, responsibility for shaping the knowledge and practice of a community". The author recognised that this is challenging given that classrooms are conservative spaces where the teacher is the sole dispenser of knowledge and the student the recipient.

The above discussion provides me with a conceptual framework to analyse how pre-service teachers develop their pedagogy for science teaching. In summary, the following points emerge in relation to the analysis:

- ◀ Science students acquire their disciplinary knowledge in communities of practice. There is a disconnect between the way in which knowledge is presented as an accumulation-of-facts as opposed to the way in which scientists produce knowledge through a process of peer review.
- ◀ Sociocultural theory provides a useful lens in science education as it shows how knowledge is mediated in a social setting. Vygotsky's notion of the ZPD is particularly significant in developing students' higher-order thinking skills.
- ◀ The use of semiotic tools in multiple representations is important in the teaching and learning process as teachers use them to explain concepts while students use them to develop understanding of a concept.
- ◀ Teachers should promote science-as-practice as it exposes students to epistemic practices to develop scientific knowledge.
- ◀ It is essential to know what epistemic frame is adopted during teaching as the transmission mode encourages science-as-fact whereas a sociocultural approach supports science-in-the making.

The research questions that I frame relate to concerns that I have about how pre-service science teachers develop their pedagogy for teaching. These are:

1. What semiotic tools do pre-service science teachers use to appropriate knowledge through representational activity?
2. What epistemic approach do pre-service science teachers use to promote science-as-practice in the classroom?

Teacher Education for Transformative Agency

3. Do pre-service science teachers scaffold concepts to promote higher-order thinking in the classroom?

In the following section, I examine vignettes of pre-service science teachers' presentation of lessons in different contexts. Each teaching and learning context is unique, but it is a social activity which I am interested in analysing in terms of how knowledge building unfolds in the shared space of the classroom. I first present an example of my own practice as an opportunity for self-reflection. Schussler et al. (2008) have argued that in teacher education, reflection before, during and after a lesson is necessary to implement new classroom teaching practices.

Reflections on my own practice

I introduce my students to a simple physics lesson that deals with the concept of refraction that is centred on the notion of a “Big Idea”. This entails an observable phenomenon for which a plausible explanation must be provided (Harlen, 2010). I emphasise the macro-level observable using our senses, and the micro-level explanation, which requires a model or theory to help explain the phenomenon. I also consider this learning environment to be the creation of a science community of practice (Stroupe, 2014). The lesson is presented as a model that could be embraced by pre-service teachers when they enact their own lessons, as it demonstrates science-as-practice and the use of different semiotic tools, in addition to the verbal and non-verbal (such as gestures) explanations used.

In the lesson, I use a simulation to develop the meaning of the concept of refraction. Computer simulations can provide learning opportunities that allow students to deal with virtual phenomena and to manipulate or modify parameters that would otherwise be impossible to observe (López & Pintó, 2017). Figure 9.2 shows a screenshot of the simulation for the bending of light.

Through a series of questions to encourage students to think beyond the obvious, and to scaffold their thinking, we arrive at the definition that the light must strike obliquely, and be moving from one medium to another of different optical density, for bending (refraction) to take place. Data is then collected by tabulating the angle of incidence and refraction using a protractor. Using Snell's law we find the refractive index of glass by plotting a graph and emphasising the dependent and independent variables. I also explain that we need to interpret the gradient of the graph and find the inverse relationship. The formation of an image by the human eye and how a rainbow is formed are also discussed. These are all applications of refraction as shown in Figure 9.3.

Exploring pre-service science teachers' epistemic agency to develop their pedagogy for science teaching

Figure 9.2 Refraction of light

Figure 9.3 Formation of a rainbow²

The content requires higher-order thinking and links the concept to the everyday experiences of the student, such as how we are able to form an image of an object that we observe. In this lesson, I would argue that I have framed most of the scientific practices outlined page 151. A question is posed about the refractive index of glass, and an investigation is planned using a simulation as a model. Multiple other representations flow from this representational model. These include the tabulation of data and the plotting of a graph. The data are interpreted and analysed using mathematics and from this, explanations are constructed and communicated. According to Stroupe (2014:492), “Teachers enacting ambitious instruction, in which students learn science-as-practice,

2 <https://bit.ly/3kMRVfv>

Teacher Education for Transformative Agency

help reframe students' roles from knowledge recipients to *epistemic agents*". I would therefore offer this lesson as a model to enact in the classroom as it embodies most of the elements of science-as-practice.

It is from the perspective of the cauldron of classroom practice that I now turn to analyse my own students' epistemic approaches. I present a multi-case study of five PGCE students presenting either a microteaching lesson to a group of learners at the university, or a lesson during teaching practice at a secondary school. All five are Bachelor of Science graduates and majored in Chemistry. The students consented to have their lessons video-recorded as part of a project that focuses on pedagogy in the science classroom. Each lesson plan was presented to me as a word document and feedback was provided immediately after the lesson concluded. The lessons and contexts in which they unfold are described and analysed in terms of the framework offered above.

Student 1

The student chose to teach the concept of magnetism to a Grade 10 Physical Sciences class. This is a microteaching lesson for learners from a middle class girls' school where there are ample resources to teach the subject as well as a permanent laboratory assistant who prepares experiments for the science classes. The school also has an impeccable record in the National Senior Certificate (NSC) examination having achieved a 100% pass rate for a number of years, and being ranked in the top 10 schools in the Western Cape province, South Africa.

The epistemic approach used by the student is largely teacher-centred with the idea of a magnetic force being foregrounded in the lesson. The transmission mode of teaching dominates, with science content presented as established fact although some of the ideas are practically demonstrated and represented diagrammatically. The core ideas are referenced to the textbook, which represents an accumulation of science facts or canonical knowledge. Student 1 exemplifies this as follows:

I think in the textbook they write it like this.

What is magnetism ... what do you think it is? I have two definitions here.

You will see the ends of the magnet have...

This could be labelled a conservative approach where learning takes place through rote learning and memorisation of facts. The teacher retains cognitive authority and the learners are not engaged in science-as-practice. When

questions are posed and the learners respond, there is then a mere confirmation of their answers as either right or wrong. There is no engagement to elaborate and discuss the answers. Thus there is no shift in cognitive authority so that the learners become epistemic agents. It is evident from the analysis of the lesson that limited effort was made to represent the concept of magnetic force through different semiotic tools. The notion of science-in-the-making from a sociocultural perspective was absent, and there was no scaffolding of the concepts to promote higher-order thinking.

There were no restrictions placed on the pre-service science teachers in terms of the approach they could use to teach a particular topic, especially if it was taught at the university to a group of learners during microteaching. An opportunity to present science-as-practice was therefore lost with a group of learners well suited to such an approach.

Student 2

A microteaching chemistry lesson is presented to a group of learners from a high school where the languages of teaching are Afrikaans and English. The pre-service science teacher presents this particular lesson in Afrikaans. The school also has well-established science laboratories having recently refurbished them.

The lesson focuses on the core idea of a chemical or physical change. At the start of the lesson, the group of learners are called to the demonstration table to observe a certain reaction. The pre-service science teacher had prepared the same sample the day before in the event of something going wrong. She asks the learners to observe and predict whether a physical or chemical change will take place. As the reaction proceeds, she appears a little impatient and states the following:

You have to wait a little and then you will see a colour change. This is normally an indication of a chemical change.

Having asked the learners to state what they think the reaction is, she then gives the answer herself. This is a clear indication of her retaining cognitive authority by giving the correct answer even before the learners respond. There is no room for alternative answers, or an opportunity to speculate and discuss events as they unfold in reality.

Later on, the learners engage in a hands-on activity using material to represent a model of a chemical reaction such as the formation of water. This is clearly science-as-practice in action because models are used to explain a certain

Teacher Education for Transformative Agency

phenomenon. However, the moment the model deviates from the correct scientific representation the student teacher offers the correct answer.

This turned out to be an interesting lesson in that elements of science-as-fact and science-in-the-making are present. The pre-service science teacher resorts to ultimately retaining cognitive authority, and fails to allow mutual knowledge building in the classroom for the learners to develop their role as epistemic agents. There is an attempt to use different representations, but scaffolding to allow deep learning was somehow negated when the student teacher intervened by providing the answers when there was potential to engage the learners in discussion.

Student 3

A chemistry lesson, which focused on chemical bonding, is presented during microteaching at the university. The learners are from a poorly resourced school and science has not been one of the school's strong subjects as evidenced by the NSC results. The number of learners doing science has remained low over the years, despite the support that the university's Chemistry department provides to promote science at the school.

The pre-service science teacher starts with a question: Where have you come across chemical bonding? In your books?

Learner: In Life Orientation.

Student teacher: So is it to bond your family members? Okay, nice one.

After this opening, the lesson is presented with a statement of the science facts and no engagement of science ideas with the learners. Formal definitions are provided so that the notion of science-as-fact dominates. Cognitive authority resides with the student teacher, and as a result, the learners do not become epistemic agents. This vision of science is a conservative approach to teaching and does not promote science-as-practice. Learners' ideas are not supported to come to the fore through engagement in discussion, or using models to explain phenomena. This particular class exemplifies one where teacher-talk dominates and the building of a community of practice is absent. There is also no attempt to promote the use of multiple representations, or to scaffold any concepts to stimulate higher-order engagement with the concepts.

Student 4

The student presents the topic of mechanical energy to a Grade 10 class at a dual medium school in a small town during teaching practice. Both English and Afrikaans are used during the lesson. The school is reasonably resourced with access to some laboratory and audio-visual equipment.

The student opens the lesson by asking if anyone can provide a definition of mechanical energy. A learner responds with a good answer, which the student teacher confirms as correct. The lesson proceeds with constant questions being asked of the learners. Derivation of units is done to confirm that energy is measured in Joules. A pendulum is then demonstrated to explain conservation of mechanical energy. Graphs are drawn to further illustrate the point. The learners are then given a few questions to solve where they apply the law of conservation of mechanical energy.

This is also an interesting lesson to analyse as both science-as-fact and science-as-practice are present. When learners answer the questions, the core science facts are merely stated and confirmed by the student teacher. The use of the pendulum to explain the concept of conservation of mechanical energy provides evidence that the student teacher attempted to engage in different representational activities.

The fact that the student teacher ensures that all the answers are scientifically correct with no room for discussion means that cognitive authority still resides with her. There was also no attempt made to promote higher-order thinking by scaffolding the concepts. In fact, the lesson seemed to be well rehearsed with a reluctance to deviate from the script. This is another opportunity missed for learners to develop epistemic knowledge. They could have been engaged in meaningful argument, a feature of scientific practice.

Student 5

The student taught chemical solutions to a Grade 11 science class at a township school during teaching practice. The school is poorly resourced, but promotes science teaching and learning through active participation in support programmes provided by the university.

The student sets up a data projector, which he connected to a laptop computer. He proceeds to present the core concepts of the lesson using PowerPoint. Some of the key concepts are explained using a simulation. The learners then

Teacher Education for Transformative Agency

complete some problem-solving exercises. Statement of the science facts dominate the lesson, and the student teacher makes no effort to promote higher-order thinking.

While some elements of science-as-practice are present – such as using a model to explain a phenomenon – the student teacher largely retains cognitive authority. No attempt is made to do any science investigation, or to discuss and construct explanations. The learners are minimally exposed to use of different representational forms during the lesson. What was striking, and is something I have noticed on a few occasions, is that the learners would in unison state the definition of terms out loudly. English is not their mother tongue and the teacher would often code-switch to the local language of isiXhosa in an attempt to clarify the terms used in the lesson.

Conclusion

The pedagogy that unfolded in these five cases largely mirrors what happens in many South African classrooms. Stroupe (2014:488) referred to American classrooms when he stated: “Conservative science teaching prevents opportunities for students to become epistemic agents by promoting the completion of curricular activities rather than sense-making”. One could substitute ‘American’ with South African here and the statement would still be appropriate. Teachers are under great pressure to complete an overloaded curriculum, and hence, often resort to presenting “science-as-accumulated-knowledge” (Stroupe, 2014: 490). Whether or not they are skilled enough to shift beyond the epistemic boundaries that deliver the canons of the textbook, and expect students to deliver likewise, is a moot point (Stroupe, Caballero & White, 2018). Pre-service science teachers, from the evidence presented in their lessons, appear to be no different. Despite having more freedom to explore beyond these limitations, to a large degree they resort to enacting the curriculum through conservative teaching and fail to make inroads to become epistemic agents that advance science-as-practice in the classroom.

Reform efforts in teacher education in South Africa must focus on the establishment of a new cohort of qualified teachers who meet the standards of the *Minimum Requirements for Teacher Education Qualifications* (DHET, 2015). The policy advocates “incorporating situational and contextual elements that assist teachers in developing competences that enable them to deal with diversity and transformation” (9). Science teacher education is uniquely positioned to contribute to producing teachers who are able to adapt to a changing environment in which technology plays an increasingly significant role in teaching and learning. A sociocultural perspective addresses the interactions

that the teacher and learner should have to use the tools of the practice to explicitly mediate scientific knowledge, and bring about transformation by building a community of practice.

In this chapter, I have proposed that multiple representations are pervasive in all of their facets – verbal, textual, graphical or symbolic – as such, allowing enculturation into the science learning community. For this reason, pre-service teachers should be encouraged to use them in the classroom. However, the analysis of the lessons shows that student teachers fall short in the way they use multiple representations during a lesson. Multiple representations are also a powerful way to scaffold the learning of a concept and operate in the ZPD of the learner. Again, the pre-service teachers fail in building knowledge through science-as-practice in the classroom and developing the epistemic agency of the learners.

These findings show that some student teachers have an epistemic approach that promotes science as an accumulation of knowledge or as an established body of knowledge. Others tentatively engage in scientific practices that promote the acquisition of epistemic knowledge, but at the same time they have a conservative teaching approach that holds onto cognitive authority within the classroom. Shifting of epistemic agency, which ideally should be happening, is all too often absent.

There are many reasons for the lack of this shift towards epistemic agency. One is the fact that students feel constrained by the curriculum and only teach what is prescribed. Another is that they come from a discipline that places an emphasis on the correctness of scientific facts; therefore, they only provide learners with textbook-driven answers. It would take more than just showing them how it could be done, but perhaps our assessment methods should explicitly focus on the extent to which scientific practices are adopted in the classroom.

As a science teacher educator, I have to acknowledge that doing work that disrupts the thinking of the pre-service science teacher is difficult, especially if it goes against years of doing science where the teacher retained cognitive authority. If the expectation is that the pre-service teacher must make a shift and appropriate epistemic agency, and in turn foster the same in their classrooms, then there has to be a fundamental change in the way we teach and learn science. We want to make science more meaningful so that the learner sees the value of the discipline in everyday life, but we continue to treat learners as passive recipients of knowledge. This tension is unlikely to go away so we must take small steps to bring about a change in mindset in our pre-service science teachers who are the teachers of tomorrow.

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