Knowing, acting and being: Epistemological and ontological access in a Science Extended Studies course

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Abstract
Gross participation and throughput rates in higher education institutions in South Africa indicate an inequitable and poorly functioning system. This interpretive study argues for an approach that enhances epistemological and ontological access and examines how an intervention that includes an overt approach in dealing with the nature of science, coupled with student involvement in an independent research project in a Science Extended Studies course, can enhance such access to higher education study. Analysis of project outcomes and student critical reflections indicated access to scientific and academic Discourses was enhanced through: developing improved procedural and conceptual scientific knowledge; meaningful engagement with the language, norms and conventions of the Discourse; integrating everyday knowledge into more abstract scientific knowledge; awareness of the process of validation of scientific knowledge, of the limitations of science, and of the impact of science on society; and transforming personally by developing scientific discursive identity and a sense of belonging. In conclusion, it is argued that curriculum interventions that focus on epistemological and ontological aspects of learning could appropriately be used throughout the higher education science sector.

INTRODUCTION

... learning is not confined to the heads of individuals, but involves integrating ways of knowing, acting and being within a broad range of practices. (Dall’Alba and Barnacle 2007, 683).

The agenda for the South African higher education sector since the establishment of a democracy in 1994 has seen, amongst other things, increased participation (NHCE 1996) and transformation guided by principles of equity and redress, quality, effectiveness and efficiency (DoE 1997). The sector as a whole has expanded considerably in this time, but a cohort study, tracking the numbers of students graduating after three, four and five years, shows uneven gross participation rates (total enrolment as a percentage of the 20–24 age-group in 2005 was 60% for whites, 51% for Indians, 12% for coloureds and 12% for blacks1) as well as poor
throughput rates (graduation of the 2000 intake in the life and physical sciences and the mathematical sciences in regulation time at contact higher education institutions was 21% and 24% respectively; (Scott, Yeld and Henry 2007)). This suggests significant shortcomings in terms of meeting the goals of the democratic agenda and Scott, Yeld and Henry argue for systemic responses which include ‘reform of core curriculum frameworks ... [and] development and implementation of effective teaching approaches’ (2007, viii).

One of the more recent institutional, government-driven responses to address the issues of access and success has been to fund the establishment of extended programmes in most higher education institutions country-wide. These programmes extend the three-year degree to four years with courses in the first and sometimes second year being designed to align better with students’ educational backgrounds and allowing for more time on task in both structured and independent study in a supportive environment. The relatively high teacher to student ratios in the initial years restricts student numbers, and as a result the programmes do not make a huge impact on the sector in terms of gross participation rates, although they do offer access to students who otherwise may not have been able to enter a particular higher education institution. Perhaps the value of these programmes should not only be measured in ‘efficiency’ terms (Boughey 2002), but also in terms of the opportunities they offer as sites for curriculum innovation and research that can engage with some of the pedagogical issues at stake. Cognisant of the need to be ‘doing something different’, the Rhodes University Science Extended Programme is seeking ways to improve practice, and a current curriculum review process has prompted an introspective look at the teaching and learning philosophy that underpins the pedagogical practices in the programme. This article forms part of that reflective process.

THEORETICAL FRAMEWORK: WAYS OF KNOWING AND LEARNING

Our thinking on teaching and learning in modern times, influenced by the rationalist philosophers Descartes and Kant, often assumes that learning is an individual activity and that the learner (subject) is separate from the knowledge (object) (Archer 2000; Luckett and Luckett 2009). This cognitive way of knowing also assumes that acquisition of autonomous, decontextualised knowledge, concepts and skills is simply a process of transfer from teacher to learner, and non-cognitive aspects of learning are not taken into account (Luckett and Luckett 2009). Learners exposed exclusively to cognitive ways of knowing tend to be good reproducers of knowledge, but have difficulty dealing with real-world problems in a meaningful way (Vygotsky 1987, in Daniels 2001). It is generally acknowledged that many South African school and even university learners, particularly in the sciences, are exposed predominantly to this cognitive, acquisition approach to learning (Holtmann, Marshall and Linder 2004).

In contrast to the cognitive learning theories, the socio-cultural view suggests learning is not necessarily an individual, isolated activity, but instead usually
takes place in a historical, social and cultural context. The focus in this view is on the ‘internalisation and appropriation of cultural tools and knowledge’ (Luckett and Luckett 2009, 470) through a process of enculturation or induction, whereby the learner accesses the Discourse of the discipline or community. The Discourse referred to here, with a capital D, is what Gee contends to be accepted ways of ‘saying-doing-being-valuing-believing’ (1989, 6). The Discourse of an academic discipline has particular epistemic values, norms and conventions, including the way knowledge is constructed, the basis for knowledge claims, and how knowledge is communicated and transmitted. These aspects of a discipline are not normally well articulated by expert members already immersed within it, but for learners to obtain ‘epistemological access’ (Morrow 1993) the discursive values and conventions need to be made explicit to learners through overt instruction (Jacobs 2007; Lesia, Marshall and Schroeder 2007) as well as through situated learning practices (Allie et al. 2009; Sadler 2009).

In its narrowest sense, the learner in the socio-cultural view of learning is viewed as a passive agent. Recently, in what has been phrased the ‘ontological turn’, there has been criticism of this emphasis on the epistemological aspects of learning (Barnett 2000; 2004; Dall’Alba and Barnacle 2007; Brown 2009), and it has been suggested that focus in higher education should be on the ‘embodiment of knowledge or knowing’ (Dall’Alba and Barnacle 2007, 681). These authors contend that ‘knowing is always situated within a personal, social, historical and cultural setting and thus transforms from the merely intellectual to something inhabited and enacted ... a way of being’ (ibid., 682). In other words, learning involves a personal transformation and the taking on of an identity that locates the learner as an active and participating member of a particular Discourse community. Unlike the more narrow socio-cultural view, where learners are enculturated into a Discourse, in this view it is assumed that learners are active agents that are transformed during the learning process (and, in turn, can influence the Discourse). In other words they develop a new identity which, according to Gee, means they become ‘a certain kind of person in a given context’ (2001, 99).

These different theoretical perspectives are not necessarily in opposition, as they foreground different aspects of learning. Whilst the cognitive view focuses on the end product of learning, the socio-cultural view emphasises the context and process of learning. The contention in this article is that by being mindful of both product and process in a holistic way can open up possibilities for a more comprehensive, and therefore ultimately more successful, learning experience in higher education contexts. As stated by Dall’Alba (2007, 683):

Knowledge remains important, but the focus is no longer on knowledge acquisition. Instead, knowing is understood as created, embodied, enacted .... Rather than treating knowledge as information that can be accumulated within a (disembodied) mind, learning becomes understood as the development of embodied ways of knowing or, in other words, ways-of-being.
PURPOSE OF STUDY
The aim of the study was to explore how curriculum innovation in an Extended Studies foundation course in the Rhodes University Science Extended Programme could be used to not only improve learner scientific knowledge, concepts and skills, but also to provide better epistemological and ontological access to scientific Discourses. The study focused primarily on student involvement in an independent research project in the second semester.

CONTEXT OF STUDY
The Science Extended Studies Programme (SESP) at Rhodes University offers a four year degree to selected students who do not meet the usual Faculty entrance requirements. The students are from poorly represented social groups, and are mainly first-generation higher institution learners that are underprepared for higher education study as a result of their educationally disadvantaged backgrounds.

Since its inception in 2005, the class sizes for the SESP have ranged from 21 to 46 students. In the first year students take three year-long, credit-bearing courses: Mathematical Literacy, Computer Skills and Introduction to Science Concepts and Methods (ISCM). The generic nature of the programme allows students to proceed to any science discipline after their first year of study.

ISCM is a foundation course which means that, although content is not generally at a first year level and students do not attend mainstream lectures, the purpose is to prepare students for higher education study. The course is integrated and interdisciplinary, and taught around a number of themes such as Matter and the Universe, Cells and Organelles, Physics of the Human Body, Our World, and Sustainable Lives. These themes are used as a basis to develop students’ understanding of broad scientific concepts (spatial and temporal scales, 2D/3D spatial awareness, hierarchies and connections, logical constructions, and diversity of things) and to introduce them to methods, skills and approaches (numeracy, literacy, drawing/diagram construction, problem solving, critical thinking, accuracy, precision, rigour, time planning, study skills) needed to function effectively within the sciences. Mainstream academic staff from a range of disciplines contribute to the course through lectures and practicals, usually each over a three week period. Two dedicated SESP lecturers (a science literacies and an academic literacies lecturer) ensure continuity within and between themes throughout the year and run numerous additional sessions with the students in order to provide content support as well to integrate academic literacies, in their very broadest sense, into the offerings of each theme. Assessment is variable, mainly formative, with exams in both June and December.

The curriculum innovations relevant to this study relate to a section dealing with the nature of science and an independent research project. The first two weeks of the ISCM course are run exclusively by SESP staff in which (a) the historical and philosophical aspects of scientific knowledge (observation, rationalism, empiricism, objectivity, uncertainty, tentative nature, socio-cultural nature), (b) methods of
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enquiry and how knowledge is constructed (methods, laws, theories, models, proofs), and (c) methods of reasoning in science (induction and deduction) are addressed through discussions and practical exercises, with students drawing on their own experiences and understandings wherever possible. This overt approach to the nature of science, supported by guest lectures and DVDs, is used to frame many other learning interactions throughout the year.

Running through the second semester is an independent project in which students, working in pairs, conceptualise, design and implement a hypothetico-deductive research project based on the influence of any environmental factor on the growth of a number of pot plants. They are required to write a proposal, conduct a literature search, draw up data sheets, set up and conduct the experiment, collect, analyse, interpret and present data in appropriate ways, with their final presentations being both in a poster and an oral form. Students are given close guidance and feedback throughout the process. As part of their learning, students are also required to reflect in formal ways on the research process.

**APPROACH TO STUDY**

This was an interpretive study based mainly on an in-depth analysis of reflective responses of students to questions on their involvement in the independent research project. The questions were as follows:

1. What academic challenges did you face in developing and conducting your independent research project? Choose ONE challenge and describe how you addressed it.
2. Did participation in the independent research project in any way change your view on science? Please explain.
3. Describe yourself as a science learner. Do you view yourself as someone who can generate new scientific knowledge?
4. If you answered yes to the previous question, have you always seen yourself this way? Please expand on your answer.

Twenty-nine of the 32 students posted electronic responses to the questions. The analysis entailed seeking evidence of learner development in epistemological and ontological terms.

**ENHANCING EPISTEMOLOGICAL ACCESS**

The independent research project was certainly effective as a means for students to gain scientific knowledge, concepts and skills. The final posters, which were assessed on a broad range of criteria such as scientific understanding of the topic, contextual basis for the study, hypothesis clearly and correctly stated, appropriate and innovative data collection, analysis and presentation, suitable discussion and links to broader context, and correct citations and referencing, were of a high standard. In their critical reflections, students most commonly cited procedural aspects of working with data (collecting, organising, interpreting and presenting), accessing appropriate scientific information, growing and maintaining plants, developing an
aim and hypothesis, producing a poster, and presenting to an audience as challenging. Of more interest in this study, however, were the critical reflections related to aspects of epistemological access.

As Holtman, Marshall and Linder (2004) state, the epistemological underpinnings of science are a contested terrain, but there is agreement generally in the science education literature that science is tentative, empirically based and socially and culturally embedded. These, and other aspects on the nature of science, were revealed in student critical reflections.

Whilst some students developed insight into how knowledge is generated,

I got new and original findings which are different to someone who has done a similar research. Even though the results may not be true for all cases but for the conditions I placed for my experiment they are true. F829.

Science is about finding an evidence that something can occur by doing experiments. M634.

Others gained an understanding of the basis for scientific knowledge claims and the tentative nature of science:

Science actually takes positive or negative results for example if the hypothesis of the experiment is proven to be wrong or right these are actually taken. M562.

Science can be tentative for this reason science cannot be proved true but a lot of evidence is introduced to support particular theory. M634.

An appreciation of the value of evidence was reflected in some comments:

It also showed me that proving something with evidence is better than assuming. F069.

I believe Science is about taking into account whatever findings you get and then try and look for an explanation around it. F403.

An appreciation for the value of a critical, evaluative and honest approach was expressed. This was largely precipitated by the fact that many did not obtain results they were expecting:

... we got unexpected results. We did not know what we were doing wrong that the research was not in our favour. In this case we had to think back to the lecture we had with Ms Simbao where she told us that we must leave space to be surprise. That strengthened us for us to put more faith in our research and the way we conducted it. If we manipulated the treatment that would mean that we are not running the experiment in a fare way. M940.
... and learn more of how to be a critical thinker and deal with the surprises that one can come across through the research. F576.

I had this misconception that there is this straight method of doing a research project and that unexpected surprises and outcomes meant that the researcher did not do the research well enough or did it wrong. F244.

... taught me to think out of the box and approach scientific questions and facts with an open mind. F491.

Furthermore, there was evidence of awareness of (a) the process of validation through repetition: ‘... you have to have a big number of samples to do your research on’, (b) the limitations of science: ‘... science can not answer everything ...’, and (c) the fact that science and scientists have an impact on society: ‘... do an experiment ... to uncover a fact that other people did not know about and that has to change their lives in a way that will benefit them as citizens’.

The above analysis of critical reflections indicate that the initial exposure to nature of science issues and later involvement in independent research work provided occasion for students to engage meaningfully with the language, norms and conventions of, and therefore start the process of gaining access to, scientific Discourses. It is useful at this stage to briefly discuss the difficulty some learners may have achieving such access.

Scientific knowledge is a formal knowledge that has been abstracted from context to develop universal principles and emphasises objectivity and quantitative measurement (Vygotsky 1987, in Daniels 2001; Bernstein 1999). Because of its abstracted nature learners often find scientific knowledge difficult to access. In contrast, everyday knowledge is that which has been acquired from a particular socio-cultural work or life context. This is embodied knowledge and therefore easily reached, although reassigning meaning out of context can be difficult (Young 2008). In a study on integrating practice-centred and scholastic epistemologies, Ellery and Lotz-Sisitka (2011), indicate that expecting students to call on their everyday, cultural knowledge not only encourages them to make explicit what they know and understand, but it also helps to integrate such knowledge into more abstract, academic contexts. O’Donoghue et al. (2007), who report on a number of empirical studies from the environmental education field, show how cultural practices can mediate learning and enhance epistemological access.

In this regard, an important aspect of the research project in this study is that it presented opportunities for students to work with their everyday knowledge in a scientific context. One student’s mother had always sprinkled rooibos tea around the base of vegetables to improve growth, which led the student to examine its chemical properties in order to explain the results of her study. In her oral presentation the student commented on her mother having been right all along, and that she was proud she could now provide a scientific reason for her mother’s beliefs. The project
had therefore not only served to legitimate her mother’s everyday knowledge, but also provided a platform for the student to access complex scientific knowledge in a productive and meaningful way.

In another example of using everyday local practices, two groups of students from drought-stricken, rural areas looked at the effect of laundry detergent in the water on plant growth. Whereas good plant growth observed in one home context resulted in a hypothesis that viewed detergents as a source of nutrients (containing mainly phosphorous), poor growth in a different home context was attributed in a second study to detergents being a source of toxins (containing nonyl phenol). That the respective experiments supported their initial observations gave rise to a philosophical class discussion on the possibility of ‘inadvertently’ achieving expected results. In the case of these two experiments the different responses of plants to detergents was most likely related to detergent concentration. In an explanation for their findings, the ‘toxin’ pair referred to chemical processes that took place at a cellular level. One of the students, in his critical reflections, stated ‘Science can help you decide what we should do [in terms of detergent concentration]. I think we should use less concentrate OMO [detergent]’. In this case not only was meaning made of an everyday practice by calling upon complex chemical knowledge, but in return science was also being called upon to possibly influence practice. Archer (2010), in her paper on transformative curriculum, argues convincingly for such an approach where cultural practices are used to access the discipline but also academic knowledge is utilised in reciprocal reflection on practices.

**ENHANCING ONTOLOGICAL ACCESS**

In the previous section data showed indications of students in the ISCM course starting to take up a scientific Discourse. Since it has earlier been argued that Discourse is central to the development of identity, this study also examined how curriculum interventions can help students develop discursive identity. With the SESP essentially preparing students for scientific study in a higher education context in any of a number of scientific disciplines, a general broad notion of scientific discursive identity is used in this study.

In response to the reflective question on whether they had always viewed themselves as generators of scientific knowledge, for many the independent project had in some way changed their view:

> No I never viewed myself as somebody who can generate scientific knowledge. I could say it is mainly because at high school I was always spoon-fed and not really given the opportunity to go out there and stand on my own in a particular project ... it [independent project] showed me that you can make a difference ... F856.

> Not ever. Science has always been something big to me, something I can’t handle. So this experiment really got me to look at Science with a different perspective, a positive one. F403.
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I never saw my self that way. I never knew the way of generate new scientific knowledge I thought it need to done by well educated and clever people only. Now that I conducted my independent research project I see my self as the person who can contribute in science industry by generate new scientific knowledge. M634.

The singularly most overwhelming response to the independent research project was linked to how the process had changed them in some way and how they felt about themselves, with many commenting on feeling part of a scientific community:

... able to think like a real science student. M544.

... made me feel like a true scientist. F491.

... this whole process changed me as a science student and that is in a good way. M196.

... made us more aware of how we can be useful and of help to the academic world and because of that I view myself as part of the scientific community. M754.

... realised that I am not in a wrong field of study. This is because I have been feeling like I am in a wrong place and also because of the pressure from my family since they do not support me pursuing a career in science. F491.

I now view myself as someone who can generate new scientific knowledge. This is because during the course of the research project, I saw myself proving and generating information and evidence that everyone knows but in a different angle. As surprised as I was at my finding, I was happy and proud of myself because I was now acting like a new young scientist who just got out from an egg. F279.

Participation in an independent research was eye opening. I actually felt like a scientist and I was applying all my knowledge of what I learned in the past. This research project allowed me to dream of how the future could be like with me being a scientist and that made me realise that I really wanted to be a scientist more then I had ever thought about in the past. F439.

As important, involvement in the process had indicated to one student that she clearly was not in the right field:

... discovered that it is not what I want to do with the rest of my life. F323.

Gaining access and becoming part of a particular community is difficult and often unlikely in contrived university contexts. Allie et al. (2009) and Sadler (2009) argue that teaching practices should attempt to bear some relation to authentic activities that students will encounter later in the workplace or in further studies. In this study some students contrasted the independent research project with their school experience in
which, despite participation, science experiments were conducted in abstract contexts and in an automated manner with little understanding being generated. The authentic context was provided in this study mainly through the independent nature of the project, with students having to choose their own topic, make their own mistakes and sort them out, and devise creative ways of conducting the experiment and gathering the data. This resulted in students acting like ‘real scientists’ and feeling ‘part of the scientific community’ and therefore contributed to the process of discursive identity development.

During my research project I have encountered numerous challenges which I think were caused by the fact that I had to adapt myself to the fact that I was independent and had only my partner to rely on. … included the fact that I had to take care of the environment my research treatments were under … being responsible for the recording of data which was very important and the core underlying factor of our experiment .... M754.

The identity literature also speaks of the value of disjunctures, or as Barnett (2005, 795) puts it ‘awkward spaces’, which serve to open up opportunities for personal transformation and development of discursive identity. Dall’Alba and Barnacle (2007) contend that these difficult moments provide occasion for critical reflection. This is supported by the work of Archer (2003) on identity and agency, in which the notion of reflexivity is central. She maintains that when agents encounter structural constraints they deliberate reflexively, through ‘internal conversations’, to decide on a course of action.

In this study students encountered logistical, social and scientific structural constraints as indicated by some of the following phrases from their reflective responses:

... it was difficult for us to find a right place for our flowers ...

... working with plants I was not acquainted with ...

... challenge creating our own data sheets ...

... Working with a partner was hardest of all ...

... some information that contradicted some of our points ...

In order to overcome challenges, students of necessity used reflective processes and in so doing were beginning to act like scientists:

... we had to reconsider then we decided to water them every three days. The plants recovered and we were able to continue with our experiment. M138.
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... most academically challenging was trying to analyse how all the data could be used to display our experiment. Dealing with such a challenge required me to go back to the aim of the experiment and try to analyse what the data displayed and whether it cohered with the aim. M754.

It is suggested here that curriculum interventions that trigger reflexive deliberations have the potential to influence student discursive identity development, although it is acknowledged that not all such deliberations are necessarily productive. The work done by Luckett and Luckett (2009) in a South African higher education mentoring programme, using Archer’s (2003; 2007) four modes of reflexivity, suggests that success in higher education for many first generation students requires an ontological shift from a communicative mode of reflexivity (where one talks things through with others to confirm internal conversations) to an autonomous mode of reflexivity (where one is self-sufficient in internal dialogues). These authors further contend that in order for students to move towards the autonomous mode of reflexivity, educators should focus on creating enabling conditions for students to ‘negotiate and try out emerging identities’ (ibid. 2009, 480). Although the independent research project in this study serves to create such conditions, much more nuanced research is required to develop in-depth understanding of student reflexive processes.

CONCLUDING COMMENTS

This article started by commenting on the poor performance of students in South African higher education institutions. It was suggested that a holistic approach that focused on both product and process of learning – the ‘knowing, acting and being’ of Dall’Alba and Barnacle (2007, 683) – could be a pedagogical response worth exploring. This study has shown that curriculum interventions in a Science Extended Studies course led to students developing improved scientific knowledge and skills, being able to use and work within a scientific Discourse, and transforming personally and at least starting to develop scientific discursive identity. Furthermore, issues such as allowing students to call upon everyday knowledge to help access abstract knowledge, providing authentic learning experiences, encouraging critical reflection both informally in the project and formally subsequently to the project, and creating an interesting and motivating environment, were all possible contributory components in the process of attaining discursive identity.

Gee (1989) maintains we all have a single primary Discourse that is acquired through our initial home socialisation. This primary Discourse, which we first use to make sense of our world and interact with others, acts as a foundation for how we take up secondary Discourses such as those of our church, school, university, or any other Discourse space we may encounter. He further maintains that the more distant the primary Discourse is from the secondary Discourse, the more difficult is acquisition, and that when conflict and tension exist, acquisition can be prevented. This study was located in an Extended Studies Programme which accommodates
‘educationally disadvantaged’ students which, in this context, refers to learners from a diverse range of educational, cultural and socio-economic backgrounds that may have hindered their performance at school. Slonimsky and Shalem however, following on from Craig (1989), argue that ‘... disadvantage is a consequence of the relation between the familiar cultural context that a student has internalised, and the unfamiliar cultural and institutional context (the epistemic context of a university environment) which the student has not yet internalised’ (2004, 36). In this regard all students entering higher education institutions are to some extent disadvantaged, in that their primary Discourse does not allow them to easily access an academic secondary Discourse, a notion that is borne out by the retention and throughput statistics of the study by Scott, Yeld and Henry (2007). Curriculum interventions such as utilised in this study, that focus not only on products of learning but also on processes that emphasise epistemological and ontological aspects of learning, have the potential to transform learning and therefore should have a place throughout the higher education sector, not only in specialist extended or foundation programmes. Similar calls have recently been made by others in the South African higher education context (Allie et al. 2009; Luckett and Luckett 2009).

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NOTES

1. The naming of racial groups follows that of Scott, Yeld and Henry 2007.
2. The number of references to ‘surprise’ was in response to a guest lecture on ‘Allow yourself to be surprised by research’ by Prof. Simbao from the Fine Arts Department.

REFERENCES


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