CriSTaL
CRITICAL STUDIES IN TEACHING & LEARNING

Volume: 4 Issue: 2
Pages: 28-44 Year: 2016
DOI: 10.14426/cristal.v4i2.73

Exploring pedagogical possibilities for transformative approaches to academic literacies in undergraduate Physics

Honjiswa Conana[1a], Delia Marshall[a] and Jennifer M. Case[b]
[a] *University of the Western Cape, South Africa*
[b] *University of Cape Town, South Africa*

(Received 1 August 2016; accepted 6 December 2016)

Abstract
How can research on academic literacies throw light on the challenge to widen access to undergraduate science studies? This article explores what an academic literacies approach might mean in the context of undergraduate physics. The study examines the pedagogical practices and student learning in two undergraduate Physics courses, a mainstream and an extended course, with a particular focus on the disciplinary practice of problem-solving. Concepts from the sociology of knowledge, specifically Legitimation Code Theory, offer a useful analytical framework for characterising the movement between abstract principles and concrete contexts in problem-solving and understanding how meaning is encapsulated in the dense representations of physics. The study shows that with more time and careful pedagogical attention, the extended course was able to make more explicit the literacy practices and epistemological functioning of the discipline. The study found that the extended course adopted a more explicitly normative approach to academic literacy, i.e., inducting students into the disciplinary knowledge and norms of the discipline, but elements of a transformative approach were also evident, i.e., opening up opportunities for these norms to be critiqued and contested.

Keywords: academic literacies, physics, problem-solving, disciplinary discourse, Legitimation Code Theory, semantic waves

Introduction
Learning in higher education involves accessing a disciplinary community and its knowledge practices (Northedge, 2003). This gaining entry into disciplinary knowledge and its discursive practices is often referred to as 'epistemological access' (Morrow, 1993) and is fundamental to the contemporary imperative to widen access to higher education. This is especially critical in Science, Technology, Engineering and Mathematics (STEM) disciplines in South Africa, where student participation and completion rates remain a concern (CHE, 2013). Internationally, the accessibility of science to a wider range of students has been a

[1] Corresponding author email: cconana@uwc.ac.za

longstanding concern in science education since the 1970s, with curricula and pedagogical reforms aimed at addressing this. Initiatives have focused in particular on addressing the attrition of under-represented students, including women, from undergraduate science degrees (see, for example, Seymour & Hewitt, 1997). More recently in South Africa, calls for 'decolonisation' of university curricula have led to a renewed focus on undergraduate science curriculum and pedagogy and how to address perceptions of science as alienating and Eurocentric (see, for example, Illing and Sloan, 2016).

The field of academic literacies research has proved useful for theorising epistemological access to a range of disciplines (see, for example, Thesen & van Pletzen, 2006). How can research on academic literacies throw light on the challenge to widen access to undergraduate science studies? This paper begins by reviewing the field of academic literacies and approaches to developing students' disciplinary literacies. Jacobs, in a recent paper (2013), building on Lillis and Scott (2007), argues that much academic literacy development in South Africa is normative (that is, it inducts students into the norms of the discipline) and that more academic literacy development work is needed in a transformative vein (where students are introduced to the norms and conventions of a discipline, but also learn to contest these where appropriate).

In this paper, we take Jacob's paper as a starting point to explore what an academic literacies approach might mean in the context of undergraduate physics. We report on a study that examines the pedagogical practices and student learning in two undergraduate Physics courses, and focus our research attention in this paper on the disciplinary practice of problem-solving. Since disciplinary approaches to problem-solving emerge from the knowledge structures of the discipline of Physics itself, we mobilise concepts from the sociology of knowledge, in particular, Legitimation Code Theory, to characterise the way students engage with physics problem tasks.

Academic literacies

The concept of academic literacies has had a significant influence on student learning research since its inception in the 1990s, shifting the focus from the more cognitivist perspectives that had dominated the field until then, to more socio-cultural perspectives (Haggis, 2003). Academic literacies draws on a range of traditions, including the New Literacy Studies and socio-linguistics. Three broad approaches to developing students' academic literacy – 'skills', 'academic socialisation', and 'academic literacies' – have underpinned different forms of literacy initiatives with students (Lea & Street, 1998). The 'skills' approach has tended to take a decontextualised perspective, with a focus on grammar, syntax, punctuation and other 'surface features of text' (Street, 2009: 4). This approach is evident in many stand-alone 'English for Academic Purposes'-type modules. The second approach revolves around 'academic socialization', inducting students into the rules and norms underpinning the literacy practices of the discipline. Here, the role of the disciplinary lecturer is to make these rules and norms explicit through pedagogy. However, since these norms are often tacit and taken-for-granted by academics, Jacobs (2005) argues that collaborative partnerships between disciplinary lecturers and academic literacy practitioners may enable disciplinary practices to be more explicit and overt for students. The third approach – 'academic literacies' – is 'concerned with meaning making, identity and power and foregrounds the institutional nature of what ‘counts’ as knowledge in any particular academic context (Street, 2009: 4). Here, the purpose is also to make visible to students how the discipline, its discursive practices, norms and values might be contested or critiqued.

Lillis and Scott (2007) distinguish between normative and transformative approaches to literacy. They characterise the ‘academic socialization’ approach as normative, due to its emphasis on inducting students into the norms of the discipline, and the ‘academic literacies’ approach as transformative, due to its emphasis on opening up the disciplinary norms and ways of knowing to critique and contestation. Jacobs (2013) notes that despite this intention, transformative approaches to academic literacy praxis are not common, and she argues that there is a need to explore ‘what counts as transformative approaches to academic literacies development in South Africa’ (135). This would entail lecturers ‘making explicit the norms and conventions of disciplines, as well as opening up curriculum spaces for these to be contested’ (Jacobs, 2013: 133).

In the context of undergraduate science, as an example of a transformative academic literacy approach, consider the literacy practice of writing a science laboratory report: an ‘academic socialization’ approach would focus on inducting students into the scientific convention of writing in the third person, passive voice. On the other hand, an ‘academic literacies’ approach would explore the epistemological underpinnings of this convention, signaling as it does the removal of agency, objectivity and decontexualised universality. This might then lead to an exploration of concepts such as ‘objectivity’ and ‘value-neutrality’, to be discussed alongside the notion of the social and cultural embeddedness of scientific knowledge.

Literacies beyond reading and writing in Physics

Although early academic literacies research focused in particular on student reading and writing practices (Lea & Street, 1998), the research field now works with a more expanded definition to encompass other literacy modes. From the perspective of Physics, Linder et al (2014: 242) use the term ‘disciplinary literacy’ to refer to ‘the ability to deal competently with the various representational formats used within the discipline’. These formats would include written and oral language, graphs, diagrams, mathematics, simulations and gestures. Airey and Linder (2009: 34) view physics learning as developing ‘discursive fluency in a number of modes’ of a disciplinary discourse.

Gee’s discourse/Discourse distinction is useful for encompassing both the representational formats of a discipline (what he terms the ‘little d’ discourse) as well as the broader values, attitudes and epistemological commitments associated with those representations (the ‘big D’ Discourse) (Gee, 2005). A transformative approach to literacy would entail making these ‘big D’ features explicit to students, as well as portraying these as contestable (Marshall and Case, 2010).

Transformative academic literacies approach in science?

In the context of undergraduate science it could be argued that, while it is crucial that student be inducted into the disciplinary norms and conventions of a discipline, being exposed to critique or contestation of those norms is not important at the outset, and may in fact destabilise students. However, we suggest that creating spaces to deal with issues of identity and epistemology is also important for widening access to science. For many students taking on the d/Discourse of Physics is not an unproblematic process: it may imply values and worldviews which may be at odds with their existing identities. Furthermore, as many science educators have argued (Bowen, 2005; Lederman et al, 2002), the image of science portrayed in traditional science teaching – notably as highly objective, abstract and decontexualised; highly rational rather than requiring creativity and imagination; and as fixed knowledge rather than tentative – is at odds with how science is actually practiced. This may lead to experiences of alienation by many students. In fact, Lemke (2001: 312) questions 'whether the particular view of scientific rationality we offer is an idealisation, or a travesty, of the true scientific spirit'.

In addition, the focus on content and 'received knowledge' similarly may alienate students, through inadvertently creating the perception of science as a body of knowledge developed in some other geographical location and historical time period (Lemke, 1990), rather than as a universal endeavour involving processes of inquiry. In this vein, research on making science more accessible to learners has long emphasised the importance of foregrounding the historical and human side of doing science (see, for example, Bentley and Watts, 1986).

Recent curriculum reforms in Physics have taken up some of these critiques of how science is portrayed, and thus place more emphasis on science as a process of enquiry (for example, Etkina and van Heuvelen, 2007). These approaches also explore science as a way of knowing in relation to other knowledge forms to counter the 'scientism' which is sometimes portrayed in undergraduate science degrees (i.e. the view that science is the most authoritative viewpoint in relation to other forms of knowledge).

Insights from the sociology of knowledge for the teaching of Physics

The field of academic literacy is particularly concerned with disciplinary practices, and this focus on practices could be construed as generic in focus and therefore neglecting a focus on knowledge. However, this presents something of a false dichotomy between social practice and knowledge: disciplinary practices are not arbitrary, but reflect or emerge from disciplinary knowledge structures. In this paper, we draw on concepts from the sociology of knowledge to give insight into aspects of student learning and pedagogical practices in Physics, in particular the practice of problem-solving.

Basil Bernstein, the eminent sociologist of education, argues that Physics as a discipline epitomises a *hierarchical knowledge structure*, being a 'coherent, explicit and systematically principled structure, hierarchically organised' (Bernstein, 2000: 160). As the name implies, hierarchical knowledge structures develop through the integration and subsumption of new knowledge. This 'verticality' (Muller, 2007) implies that physics knowledge abstracts from context-specific, real-life contexts to decontextualised principles. These features of the knowledge structure are evident in the literacy practices: the prevalence of dense nominalisations (in which complex processes or phenomena are condensed into a single word, for example 'ionisation'; see Brookes, 2006); the use of passive voice and third person in writing (see, for example, Halliday & Martin, 1993); and the movement from concrete representations to abstract, dense representations in physics problem-solving.

Physics is concerned with the understanding and prediction of phenomena in the natural world, through the development of idealised models of phenomena, which are then related back to experimental observation. Modelling is therefore a key aspect of doing physics. One of the key aims of undergraduate Physics education, as captured in key international policy documents on Physics graduate attributes (for example, Institute of Physics, 2011), is to develop students' capacity to formulate and tackle problems in Physics in the way that expert physicists would.

However, research studies show that many students struggle to approach physics problems with an understanding of modelling. One of these seminal studies (van Heuvelen, 1991) notes that while expert physicists rely on qualitative analysis and qualitative representations to understand a physical process, students instead view problem-solving as 'almost entirely formula-centred – devoid of qualitative sketches and diagrams that contribute to understanding' (891).

The key point here, as Bernstein notes, is that knowledge structure does not equate to curriculum structure or pedagogical structure. In other words, the knowledge structure of Physics is often not made sufficiently explicit to students through the pedagogy. This is because many of the representational aspects of Physics tend to be taken for granted in teaching: although problem-solving is demonstrated in lectures, often the modelling and qualitative representational aspects are glossed over, and what students see written down by the lecturer is merely the mathematical representation of the problem situation (see, for example, Leonard et al, 1996). By not making the representational aspects of the discipline explicit enough in teaching, students are not fully inducted or socialised into the disciplinary discourse.

In order to analyse how teaching might make the representational aspects of Physics more explicit to students, we turned to concepts drawn from Legitimation Code Theory (LCT) (Maton, 2014), which builds on Bernstein's work. In particular, we drew on the 'Semantics' dimension of LCT with its analytical concepts of semantic gravity and semantic density. *Semantic gravity* is defined as the extent to which meaning 'is related to its context of acquisition or use' (Maton, 2009: 46). When semantic gravity is weaker, meaning is less dependent on its context. Advanced-level Physics operates with abstract, decontextualised concepts and principles, so could be said to have a weaker semantic gravity. *Semantic density* is seen as the extent to which meaning is concentrated or condensed within symbols (a term, concept, phrase, expression, gesture, etc.) (Maton, 2014). Physics has stronger semantic density, because meaning is condensed within nominalisations (that is, scientific words or phrases that are dense in meaning) and within the multiple representations (graphical, symbolic, diagrammatic, mathematical, etc.) with which the discipline is represented semiotically.

Although semantic gravity and semantic density are independent constructs, in a discipline like Physics they often tend to be inversely related (Lindstrøm, 2010): abstract, decontextualised constructs have weaker semantic gravity but tend to be represented in condensed symbolic form, with stronger semantic density. In order to visualise the relative strengths of semantic gravity and semantic density (SG and SD) over time, Maton (2014) has developed an analytical method of *semantic profiling*. This indicates in the form of a diagram how the strengths of SG and SD vary over time. The strengths of SG and SD are represented on the y-axis, with time on the x-axis (see Figure 2-5 below).

When tackling a physics problem, students tend to adopt the formula-centred approach that van Heuvelen (1991) describes. In other words, they often leap straight into abstract mathematical formulas, without first starting with the concrete physical situation of the problem, and modelling this using qualitative representations. In LCT terms, students tend to move too quickly up the semantic gravity continuum away from the concrete physical situation to abstract mathematical representations. In terms of semantic density, they move too swiftly to semantically dense representations (mathematical equations) without first ensuring that these are meaningfully related to the concrete situation of the problem (see Georgiou et al, 2014).

In order to address students' difficulties with problem tasks, 'reform' curricula (for example, Etkina and van Heuvelen, 2007) explicitly emphasise that 'thinking like a physicist' requires the use of multiple representations in tackling physics problems. Others argue for the importance of creating a 'representation-rich learning environment' (Rosengrant et al, 2009: 010108-2), which explicitly helps students learn how to use representations, to appreciate why certain representations are useful and to see the epistemological underpinnings of these representations, thus developing students' 'meta-representational competence' (Kohl and Finkelstein, 2008: 010111-11). In order to tackle a mechanics problem as an expert would, students would be expected to engage with the following representations:

- the *verbal* representation of the process (requires reading and unpacking the problem statement).
- a *pictorial* representation – a sketch (requires modelling the situation to capture the important features of the problem, and modelling the object of interest as a point-particle).
- a *physical* representation – a force diagram/ free-body diagram (FBD) (requires visualising the problem, identifying the system and the forces acting on it, and translating words to symbols).
- the *mathematical* representation to describe the process by using basic physics principles (law & equations) – requires solving the problem by using appropriate mathematical representation.

Tackling a mechanics problem, then, entails starting with the concrete physical situation (with stronger semantic gravity) set out in a problem statement (an elaborated, verbal representation, with weaker semantic density). As the concrete situation is modelled and simplified, and abstracted to the level of principles and laws, the semantic gravity is weakened. At the same time, the elaborated, verbal representation is condensed into a sketch of the situation, and then further condensed into the vectors and symbols of a force-diagram, and finally into the dense mathematical formalism. The placing of the physics representations on the semantic continuum is illustrated in Figure 1. At the bottom of the semantic continuum in Figure 1 is the verbal representation of the concrete task situation. Moving up the continuum, the representations become semantically denser and more abstracted from the specifics of the problem context (weaker semantic gravity). At the top of the semantic continuum is the 'assess' stage where the quantitative solution is linked back to the concrete situation. Lecturers' and students' movement between these representations is portrayed on semantic profiles (see Figures 2-5).

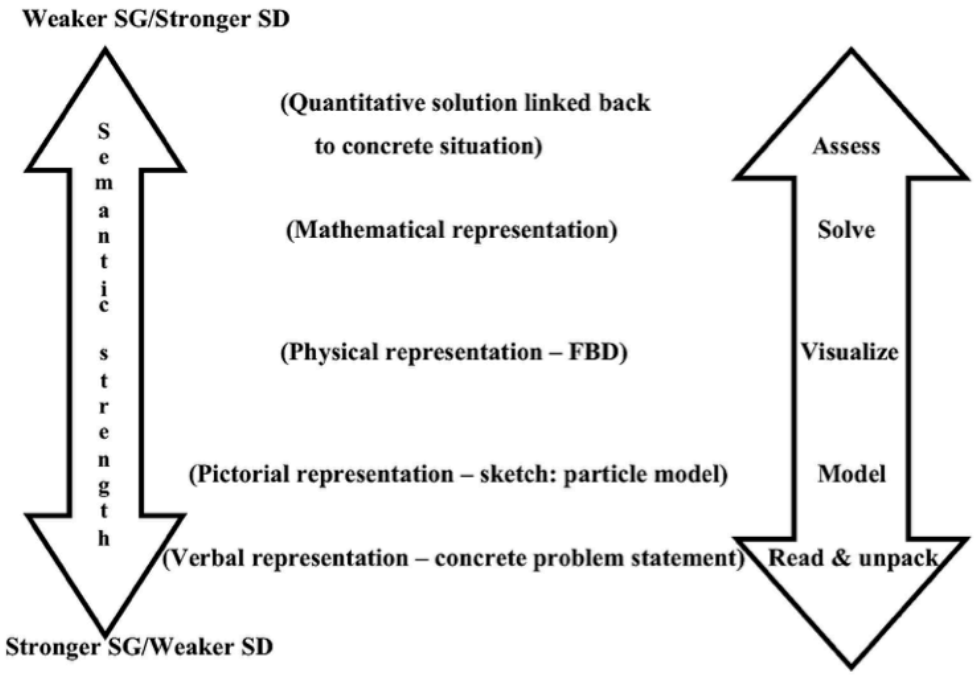

Figure 1: Semantic gravity and semantic density in relation to representations in mechanics problem solving

The context of the study and its methods

This paper draws on a larger study (Conana, 2016), located in two first year undergraduate courses in a single Physics department – a traditional, mainstream course and an extended physics course. The extended physics course forms part of an extended BSc degree programme; these extended degree programmes were introduced into South African higher education institutions to widen access to undergraduate studies, and improve student success.

Lecturers widely regarded by their colleagues and students as excellent teachers teach both courses. Although both courses cover the same first year physics topics, the extended course is spread over two years, which allows more time and curriculum space for foundational provision and for the introduction of some of the physics 'reform' initiatives detailed above: a greater focus on the nature of physics knowledge, on the processes of scientific enquiry and modeling, and a focus on 'thinking like a physicist'. The extended physics course also explores science as a way of knowing in relation to other knowledge forms to counter the tendency towards 'scientism' discussed earlier. It is important to note here that the focus on disciplinary practices and ways of knowing does not imply that disciplinary knowledge is devalued (as some sociologists of education have suggested, see for example, Muller, 2014). Rather, the physics education reforms described above have arisen from a recognition that traditional undergraduate curricula have tended to place exclusive emphasis on physics content knowledge (principles, concepts, laws), and have not paid sufficient attention to the inquiry and modelling processes of science.

The course has an emphasis on making explicit the various representational formats used in Physics (this was enhanced through a collaborative partnership between the discipline lecturers and an academic literacy practitioner) (see Marshall et al, 2011). The course also presents the discipline of Physics in its wider social, political and environmental context. In this way, the purpose of the course is to induct students into the discipline (a normative approach), while at the same time developing their capacity to stand outside the discipline and take a critical stance (developing a transformative approach).

In the next section, we use research on pedagogical practices and student learning to explore what an academic literacies approach might mean in the context of physics problem solving. Data is drawn from video-recordings of lectures and of students working on problem tasks, as well as from in-depth interviews with students. Semantic profiles are constructed to represent the shifts between representations, and the discussion will focus broadly on how these semantic profiles shed light on the approaches to academic literacy development adopted in these two courses.

Pedagogical practices in tackling physics problems

As noted above, students' induction into a discipline is made easier if the norms and literacy practices are made more explicit through pedagogy. This section examines how these two Physics courses go about inducting students into the disciplinary ways of solving physics problems. To do so, LCT tools were used to analyse the pedagogical approaches.

The two courses varied in the way that problem tasks were dealt with in lectures, with different degrees of explicitness about the use of representations. Starting with a verbal representation of the problem situation, the lecturer in the mainstream course tended to set up a problem orally, whereas the lecturer in the extended course usually started with a written problem statement, which the students were required to read and unpack, paying particular attention to nominalisations and semantically dense words or phrases (such a 'constant acceleration').

An analysis of two lecture sequences in the mainstream and extended courses is shown in Figures 2 and 3, which show the movement between representations up and down the semantic continuum. In the mainstream sequence (Figure 2), there is a rapid shift up the semantic continuum, with little time spent on qualitative representations and the meaning of the problem context being quickly condensed into a mathematical representation. In the extended lecture sequence (Figure 3), the semantic profile is flatter initially, with more time spent unpacking the verbal representation, and more time for explicit focus on modelling the problem and the detailed aspects of constructing a free-body diagram before moving to the mathematical representation. The semantic profiles in Figures 2 and 3 indicate that extra time in the extended course enabled the lecturer to place more explicit focus on the representations required for successful problem-solving. There was less of the taken-for-grantedness of representations which research shows is often prevalent in first year teaching (for example, Leonard et al, 1996).

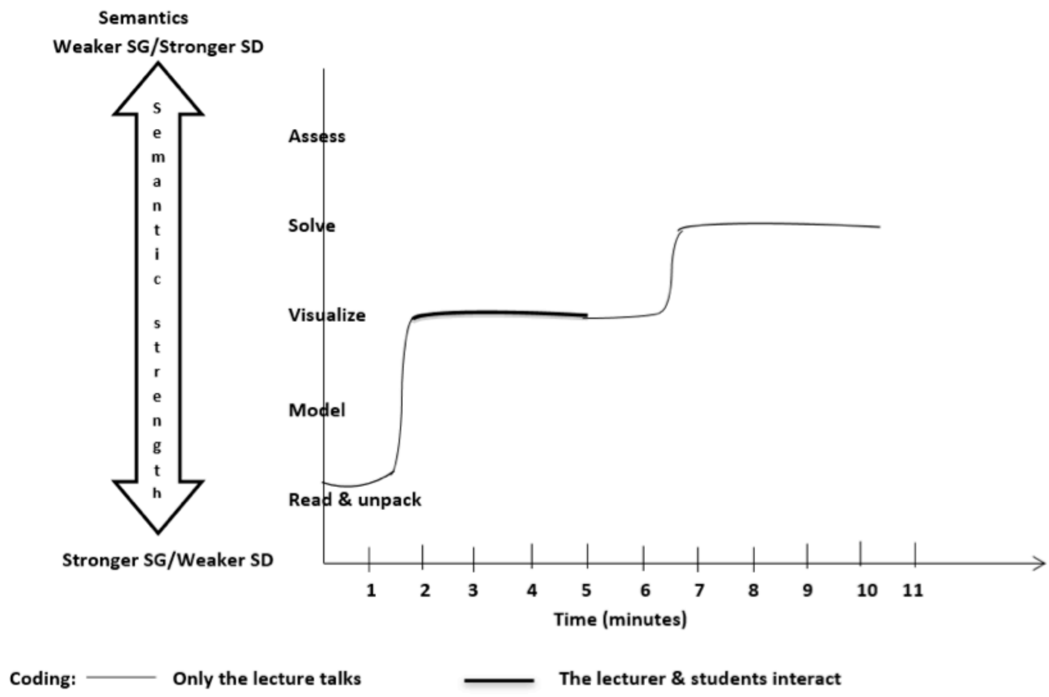

Figure 2. Semantic profile of lecture sequence in Mainstream course

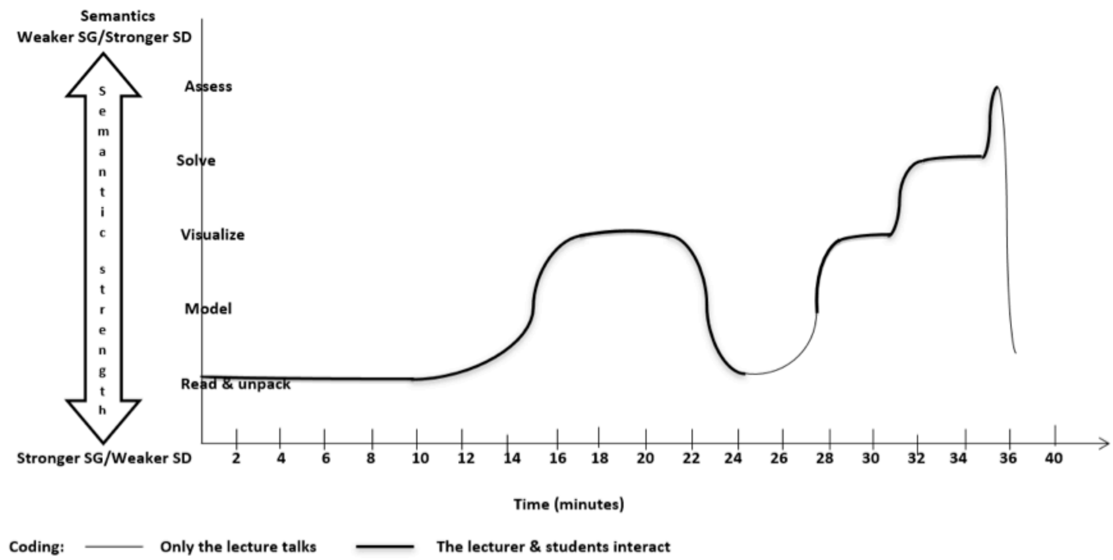

Figure 3. Semantic profile of lecture sequence in Extended course

The video-data from the lecture sequences shows that the lecturer in the extended course presented representations not merely as a step in a problem-solving procedure, but dealt with the epistemological commitments reflected in semiotic forms. For example, when a force-diagram representation is drawn in Physics, the forces acting on an object (such as a car, or a box) are represented on the diagram, and the real-life object is modelled as a point particle and represented as a dot on the diagram. The lecturer emphasised that this representation is not merely a convention, but pointed to an important underlying epistemological feature of physics, i.e. the idea that physics provides us with simplified models for making sense of the complex physical world.

In the extended course, there is an explicit focus on the qualitative representations (pictorial and physical representations, such as force diagrams) needed for successful quantitative problem solving. There is also more movement up and down the semantic continuum between representations. In addition, there is more evidence of the lecturer attending to 'meta-representational competence' (Kohl and Finkelstein, 2008) by discussing the purposes of representations and the epistemological commitments reflected in these representations. In summary, the pedagogy in the extended course showed a greater normative, 'socialisation' approach to academic literacies, through its explicit focus on the norms and literacy practices of the discipline. The pedagogy in the extended course also had elements of a transformative approach, through emphasising the important underlying epistemological aspects of physics.

Students tackling physics problems

In our study, several student groups were observed tackling physics problem tasks on the same mechanics topic as in the lecture sequences above. In this paper, we examine the semantic profiles for two representative student groups, one in the mainstream course and one in the extended course. Figure 4 and Figure 5 below present the semantic profiles for the mainstream and extended student groups respectively. From the broader study it was evident, as illustrated here, that the semantic profiles of the students' approaches to tackling the physics tasks take on a similar form to the particular semantic profile of each lecture sequence (Figures 2 and 3 above).

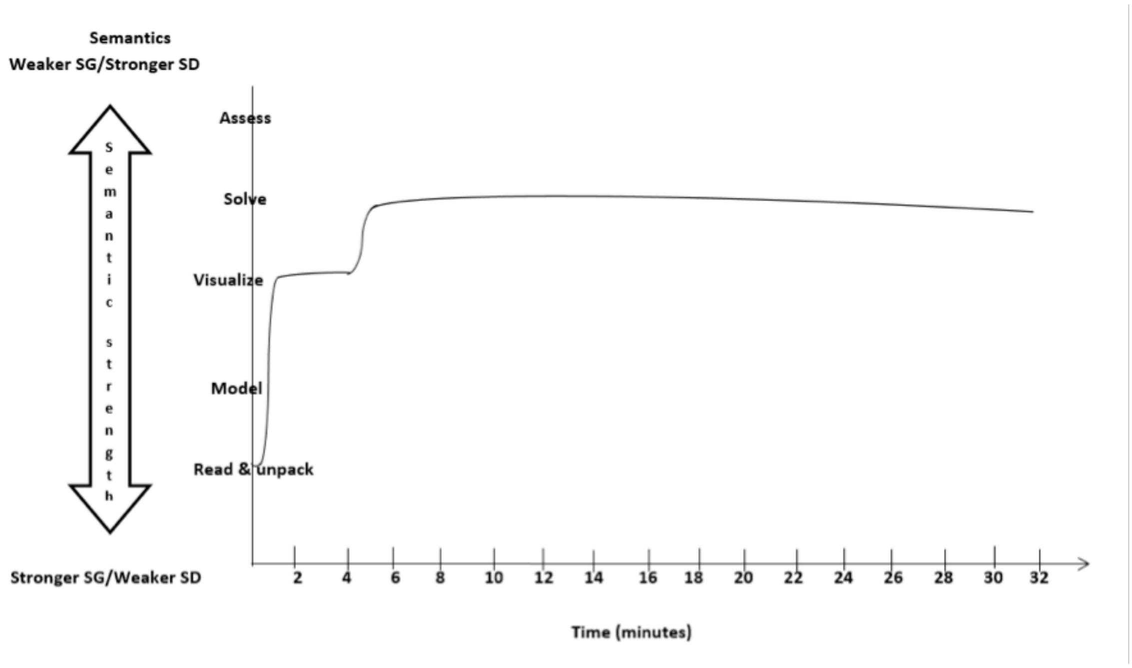

Figure 4. Semantic profile of students tackling a task in the mainstream course

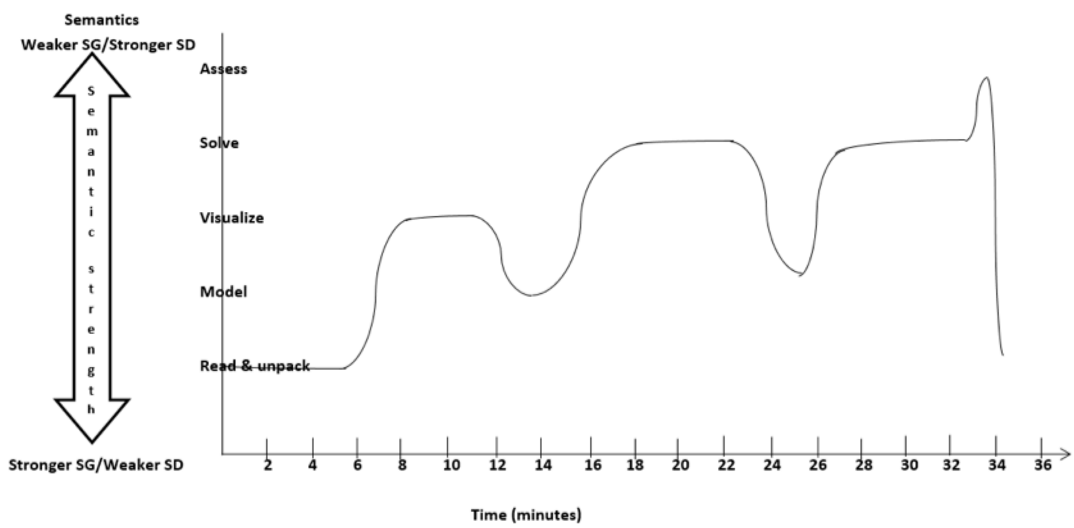

Figure 5. Semantic profile of students tackling a task in the extended course

The technique of semantic profiling offers a useful 'at a glance' portrayal of how representations were used by the student groups in tackling problem tasks. In the case of the mainstream group, just as was evident in the semantic profile of the mainstream lecture sequence, the students move up the semantic continuum swiftly to draw a force diagram and then move to the mathematical representation of the problem. The semantic profile for the extended group, by contrast, is flatter initially, with students spending more time discussing the verbal representation of the problem and modelling the problem situation before drawing a force diagram and then moving to a mathematical representation. They shift up and down the semantic continuum as they tackle the task.

Video-data provided further insight into students' use of disciplinary representations. The mainstream group read the problem statement, and then proceeded straight to a force diagram and to mathematical representation. The extended group read the problem statement and then started by discussing the situation and interpreting the problem statement:

> *So, here… the system is at rest, so the acceleration is zero. So we are going to use static friction. So we have two separate diagrams for each of these [crate and hanging mass]. The system is at rest, so the net force is zero.*

In modelling the two objects, the extended group represents these as point particles. They explain:

> *The dot represents the crate, we model it as shapeless in 2 dimensions.*

By contrast, the mainstream group did not seem aware of the epistemological implications of the point particle representation; they felt that the 'dot' was confusing:

> *For instance, when drawing the block, you could see exactly what and where the block is, but the dot will be hidden when indicating the axes…. The dot will be difficult to see.*

The use of force diagrams is also distinctively different in the mainstream and extended groups. In the mainstream group, the force diagrams were drawn mechanically, and were not really put to use in setting up the mathematical representations, despite the function of force diagrams being to help in the move from the concrete situation to a mathematical representation (Rosengrant et al, 2009). This was evident when the group reached an impasse later with the mathematical representation, due to not having interpreted the physical situation at the outset, and they argued at this late stage about whether the objects were stationary or not. When asked about the use of the force diagram representation, one student in the mainstream group noted vaguely that he would 'generally draw or just sketch something', By contrast, as shown in the quote below, the student group in the extended course took great care in drawing their force diagrams, so that the relative sizes of the force vectors represented the concrete, physical situation; they showed greater degree of 'meta-representational competence' in being able to articulate the purpose of the force diagram:

> *The [force] diagram gives you an indication of the relative sizes of the forces so you know that the system is at rest or moving…. The size of the vectors depends on the sum of the forces in that direction….if it [the object] is standing still, that means that the vertical forces should cancel each other.*

In summary, if 'thinking like a physicist', as noted earlier, entails the use of qualitative analysis, modelling and qualitative representations to understand a physical process, rather than just mathematical representations, then students' problem-solving practices in the extended group were more congruent with expert physicist practices.

Discussion and conclusion

This study has shown that, with more time and careful pedagogical attention, the lecturer teaching the extended course was able to make more explicit the literacy practices and epistemological functioning of the discipline. The data, presented in the form of semantic profiles, video and interview excerpts, indicate that when the pedagogy was aimed at making explicit to students the discourse features and representations entailed in problem solving, this led to students' greater 'disciplinary fluency' with these disciplinary representations. Students' use of qualitative representations as a precursor to mathematical representations, and their movement between representations, showed evidence of taking on a 'thinking like a physicist' approach. From a normative academic literacy perspective, this illustrated students beginning to be inducted into the disciplinary norms and practices. The pedagogy also had elements of a transformational approach, emphasising the modeling enterprise central to physics and exploring the usefulness of different representations. In tackling problems, the students in the extended group displayed a greater 'meta-representational competence' than their mainstream counterparts, and a greater awareness of the epistemological commitments implicit in representational forms.

The primary focus of undergraduate science education is without doubt the induction of students into the disciplinary knowledge structure and ways of thinking. This is in itself significant. Inducting students into a discipline without necessarily critiquing disciplinary norms could be viewed as 'transformative' in a broader sense. As Wheelahan (2007) notes, physics knowledge would count as 'powerful knowledge' and accessing that knowledge and ways of thinking can be seen to be transformative in itself.

Despite the primary focus on inducting students into the disciplinary norms, there is an argument to be made that a more critical angle on how the discipline is portrayed is also important for making the discipline more accessible and less alienating to students. This argument has particular relevance to the current South African debate on curriculum reform and 'decolonisation', which has foregrounded the perception that contemporary scientific knowledge may be alienating because it is seen to be Eurocentric. Rather than rejecting this scientific knowledge out of hand, there is a need for pedagogical approaches that make this disciplinary knowledge more accessible and relevant to students. In this paper, we have touched on what this might mean for physics pedagogy: this could include a greater emphasis on physics as a process of modeling and predicting phenomena in the world, rather than a body of knowledge; a more explicit focus on the nature of scientific knowledge and how it is constructed; locating physics in wider social, historical, political contexts; and presenting physics as a way of knowing in relation to other knowledge forms, to counter 'scientism' perspectives that place physics at the pinnacle of a discipline hierarchy.

In terms of the theoretical frameworks drawn on in this paper, we suggest that both academic literacies and LCT perspectives offer useful and complementary perspectives in thinking about accessing disciplinary knowledge. The academic literacies perspective offers useful insights into conceptualising the accessing of disciplinary discourses. For example, this paper has illustrated the usefulness of Gee's d/Discourse distinction for framing pedagogical practices that don't just focus on making explicit to students the 'little d' textual aspects and disciplinary representations, but also make explicit the 'big D' values, attitudes and epistemological commitments of the discipline. In addition, the ideological stance of the 'academic literacies' approach (Lea and Street, 1998) draws attention to the need for contestation and critique of disciplinary norms and values. Other New Literacy and social semiotics studies provide the tools for close-up analyses of students' engagement with various representational formats used within the discipline (Airey and Linder, 2009; Brookes and Etkina, 2007; Lemke, 2001).

The academic literacies perspective is complemented by insights from the sociology of knowledge, which trace how disciplinary practices reflect or emerge from disciplinary knowledge structures. Concepts drawn from Legitimation Code Theory (LCT) offer a useful analytical framework for characterising the movement between abstract principles and concrete contexts that is entailed in physics problem solving as well as the ways in which meaning is encapsulated in the dense representations of physics problems. This particular analysis could not have been so readily achieved with the analytical tools that academic literacies offers. LCT's semantic profiles offer a useful tool for visualising the use of and shifts between representations in tackling a problem task. This complementarity of academic literacies and sociology of knowledge perspectives is also reflected in research by Paxton & Frith (2014: 181), who note that each perspective 'brings a lens that the other lacks'.

In conclusion, we return to the question posed at the outset: how can research on academic literacies throw light on the challenge to widen access to undergraduate science studies? The paper suggests that, while normative approaches naturally dominate undergraduate pedagogy, some aspects of transformative approaches to literacy development may also be important for epistemological access and for framing pedagogical transformation: explicitly inducting students into the disciplinary norms and representational formats is crucial, but so is allowing some critical engagement with disciplinary norms and ways of thinking so as not to alienate or exclude students from successful engagement with the discipline.

Honjiswa Conana is the Teaching and Learning Specialist in the Faculty of Natural Sciences at the University of the Western Cape. Her role is to support teaching and learning initiatives in the Faculty. Prior to this appointment, she worked as an academic literacy practitioner in the Physics Department at the University of the Western Cape, working in collaboration with first and second year Physics lecturers. Her research interests lie in physics education and academic literacies.

Delia Marshall is a professor in the Physics Department at the University of the Western Cape. She researches physics education, higher education and academic development. She teaches in the undergraduate programme in Physics and has also played a key role in the design and delivery of the extended programme.

Jennifer M. Case is a professor in the Chemical Engineering Department at the University of Cape Town. Her research on the student experience of learning, focusing mainly on science and engineering education, has been published across a range of journal articles in higher education. Her recent book, *Researching student learning in higher education: A social realist approach*, was published by Routledge in 2013. She is a coordinating editor for the international journal *Higher Education*.

References

Airey, J. & Linder, C. 2009. A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching,* 46(1): 27-49.

Bentley, D. & Watts, M. 1986. Courting positive virtues: A case for feminist science. *European Journal of Science Education,* 8: 121-134.

Bernstein, B. 2000. *Pedagogy, Symbolic Control and Identity.* Oxford: Rowman and Littlefield.

Bowen, G. M. 2005. Essential similarities and differences between classroom and scientific communities. In Yerrick, R. and Roth, W. M. (eds.) *Establishing scientific classroom discourse communities: Multiple voices of teaching and learning research.* Mahwah: Lawrence Erlbaum, 109-134.

Brookes, D. T. 2006. The role of language in learning physics. Unpublished PhD diss., The State University of New Jersey, New Jersey, United States.

Brookes, D. & Etkina, E. 2007. Using conceptual metaphor and functional grammar to explore how language used in physics affects student learning. *Physical Review Special Topics: Physics Education Research,* 3: 010105.

Conana, C.H. 2016. Using semantic profiling to characterize pedagogical practices and student learning: A case study of two introductory physics courses. Unpublished PhD diss., University of the Western Cape, Cape Town, South Africa.

CHE. 2013. A proposal for undergraduate curriculum reform in South Africa: The case for a flexible curriculum structure. Report of the Task Team on Undergraduate Curriculum Structure. Pretoria: Council of Higher Education.

Etkina, E. & Van Heuvelen, A. 2007. Investigative science learning environment: A science process approach to learning physics. In Redish, E.F. and Clooney, P.J. (eds.). *Research-based reform of university physics.* AAPT, Compadre: American Association of Physics Teachers, 1-48.

Gee, J. P. 2005. *An Introduction to Discourse Analysis: Theory and Method*. 2nd ed. London: Routledge.

Georgiou, H., Maton, K. & Sharma, M. 2014. Recovering knowledge for science education research: Exploring the 'Icarus effect' in students work. *Canadian Journal of Science, Mathematics and Technology Education,* 14(3): 252-268.

Haggis, T. 2003. Constructing images of ourselves? A critical investigation into the 'approaches to learning' research in higher education. *British Journal of Educational Research,* 29(1): 89-104.

Halliday, M. A. K. and Martin, J. R. 1993. *Writing Science: Literacy and Discursive Power*. London: Falmer.

Illing, N. & Sloan, A. 2016. Science and decolonization: A way forward. *Daily Maverick*, 8 November 2016. Online at: http://www.dailymaverick.co.za/article/2016-11-08-groundup-opinion-science-and-decolonisation-a-way-forward/ (accessed18 November 2016).

Institute of Physics. 2011. *The Physics Degree*: *Graduate Skills Base and the Core of Physics*. London: IOP.

Jacobs, C. 2005. On being an insider on the outside: New spaces for integrating academic literacies. *Teaching in Higher Education*, 10(4): 475-487.

Jacobs, C. 2013. Academic literacies and the question of knowledge. *Journal for Language Teaching,* 47(2): 127-140.

Kohl, P. & Finkelstein, N. 2008. Patterns of multiple representation use by experts and novices during physics problem solving. *Physical Review Special Topics – Physics Education Research,* 4 (010111): 1-12.

Lea, M. R. & Street, B. V. 1998. Student writing in higher education: An academic literacies approach. *Studies in Higher Education,* 23(2): 157-172.

Lemke, J. L. 1990. *Talking science: language, learning and values*. London: Ablex Publishing.

Lemke, J. L. 2001. Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching,* 38(3): 296-316.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L. & Schwartz, R. S. 2002. Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39: 497-521.

Leonard, W. J., Dufresne, R. J. & Mestre, J. P. 1996. Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. *American Journal of Physics,* 64: 1495.

Lillis, T. & Scott, M. 2007. Defining academic literacies research: issues of epistemology, ideology and strategy. Jo*urnal of Applied Linguistics,* 4(1): 5-32.

Linder, A., Airey, J., Mayanda, N. & Webb, P. 2014. Fostering disciplinary literacy? South African physics lecturers' educational responses to their students' lack of representational competence. *African Journal of Research in Mathematics, Science and Technology Education, (AJRMSTE),* 18(3): 242-252.

Lindstrøm, C. 2010. Mapping the hierarchy: Advancing the theoretical and practical understanding of hierarchical knowledge structure of physics. Paper presented at the Sixth International Basil Bernstein Symposium, Brisbane, Australia, June-July.

Marshall, D. & Case, J. 2010. Discourse in the learning of physics: The design of an introductory physics curriculum. *African Journal of Research in Mathematics, Science and Technology Education*, 14(2): 6-12.

Marshall, D., Conana, H., Maclons, R., Herbert. M. & Volkwyn, T. 2011. Learning as accessing a disciplinary discourse: Integrating academic literacy into introductory physics through collaboration partnership. *Across the Disciplines*, 8(3). Online at: http://wac.colostate.edu/atd/clil/index.cfm (accessed 5 October 2014).

Maton, K. 2009. Cumulative and segmented learning: exploring the role of curriculum structures in knowledge-building, Brit*ish Journal of Sociology of Education*, *30* (1): 43-57.

Maton, K. 2014. Knowledge and knowers: *towards a realist sociology of education*. London: Routledge.

Morrow, W. 1993. Epistemological access in the university. *AD Issues*, 1*(*1): 3-4.

Muller, J. 2007. On splitting hairs: Hierarchy, knowledge and the school curriculum. In Christie, F. & Martin, J. R. (eds.) *Language, knowledge and pedagogy: Functional linguistic and sociological perspectives*. London: Continuum.

Muller, J. 2014. Every picture tells a story: Epistemological access and knowledge. *Education as Change,* 18(2): 255-269.

Northedge, A. 2003. Rethinking teaching in the context of diversity. *Teaching in Higher Education*, 8(1): 17-32.

Paxton, M. & Frith, V. 2014. Implications of academic literacies research for knowledge making and curriculum design. *Higher Education*, 67: 171-182.

Rosengrant, D., van Heuvelen, A. & Etkina, E. 2009. Do students use and understand free-body diagrams? *Physical Review Special Top*ics - *Physics Education Research*, *5:* 010108.

Seymour, E. & Hewitt, N. M. 1997. *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Street, B. 2009. ‘Hidden’ features of academic paper writing. *Working Papers in Educational Linguistics*, 24(1): 1-17.

Thesen, L. and van Pletzen, E. 2006. *Academic literacy and the languages of change*. London, New York: Continuum.

Van Heuvelen, A. 1991. Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics,* 59*:* 891-897.

Wheelahan, L. 2007. How competency-based training locks the working class out of powerful knowledge: A modified Bernsteinian analysis. *British Journal of Sociology of Education,* 28(5): 637-651.