Smoothing the transition? Developing a philosophical foundation for Chemistry

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Introduction

Students entering higher education face several significant challenges (Lowe & Cook, 2003). Amongst these the shift to assuming personal responsibility for both social and academic aspects of their lives can be enormously stressful for all students. The growing sensitivity to the gap between secondary education and higher education, aided by the challenges associated with widening participation in higher education has given rise to a number of useful interventions to help students navigate this turbulent transition. The First Year Academy at Stellenbosch University (Leibowitz, Van der Merwe, & van Schalkwyk, 2009), and the development of extended degree programs across many institutions in South Africa are but two examples of such interventions (Rollnick, 2010). However, the majority of these programs tend to occur on the margins of mainstream education, in that the curricula of many mainstream courses remain essentially unchanged. One such example is the Chemistry for Health Sciences course taught at Stellenbosch University. As it stands the course focuses entirely on organic chemistry. The course curriculum has remained constant for approximately 15 years despite major changes in the demographics of the University; a substantial shift in school curriculum; and the introduction of the use of problem based learning in the health sciences faculty.

The course

Potgieter and co-workers have developed and used a conceptual test aimed at assessing the ability of students entering university (Potgieter, Davidowitz, & Venter, 2008). The test has been used in the longitudinal study on first year BSc students across a number of universities in South Africa. Without doubt the overall competency of students entering the system has been reduced (Potgieter & Davidowitz, 2010). The net result is that students entering first year chemistry have a substantially reduced set of conceptual competencies than they did in 2005 prior to the use of the outcomes based curriculum. However, the content of first year chemistry courses at both the University of Cape Town and Stellenbosch University have not changed in response. The situation in the course that I coordinate and teach 'Chemistry for Health Sciences' is perhaps one of the most extreme cases of lack of response of the curriculum to the changing environment. The curriculum follows a custom written handbook which was first published in 1998 and has not been revised since. Over the same period there have been at least three substantial changes in context:

1) The input has changed: The students are arriving at university with a different knowledge set. Overall, work by Potgieter and Davidowitz at the Universities of Pretoria and Cape Town have shown that there is a reduction in conceptual grasp of a various topics (Potgieter & Davidowitz, 2010). Some topics, for example, acids and bases, where a strong competency was observed in 2005, show a 50% reduction in competency. This is largely due to the omission of acids and bases from the final matric exam. This has the consequence of giving the topic less importance in teaching, and therefore, in an overcrowded curriculum (Umalusi, 2008) little time is taken on topics which will not directly affect the final grade of the learner. Despite this substantial loss in competency in at least one key area of chemistry, first year chemistry courses have been slow to respond. Given that most first year chemistry courses require physical science at matric as a prerequisite and set their curricula upon the presumption of coverage of certain aspects of chemistry, it is astonishing that these courses have failed to take cognisance of the change into the input.
2) The structure of the degree which follows has changed: Over the last 15 years, the use of problem-based learning has become almost ubiquitous in the health sciences (Koh, Khoo, Wong, & Koh, 2008). With this has come an increased emphasis on group work and a much earlier exposure to clinical work. However, health sciences degrees are still founded on a base of pure science. Chemistry, for example, remains a crucial part of the first year experience. An understanding of the nature and interaction of molecules is still perceived to be an important foundation for understanding biochemistry, pharmacology and physiology.
3) The modules around the course have changed: Chemistry for Health Sciences is part of a first semester program which comprises the 'Foundation Phase'. All the other courses which comprise the Foundation Phase have undergone some substantial changes over the last 3 years. The methods of assessment and an increased emphasis on group work are perhaps the most notable shifts.

Through all of this, 'Chemistry for Health Sciences' proved incredibly robust towards any changes in curriculum. In addition to which, this course focused entirely on one particular facet of chemistry. This course therefore provides something of a caricature of the reality of many introductory chemistry courses around the

country. In one sense, the resistance to change in an introductory chemistry course is justified on the basis that such courses usually comprise a small number of key conceptual areas. The length of time one might spend on a particular section, or the depth to which one wants to develop understanding will vary slightly depending on the intended outcome – a course aimed at those who are doing mechanical engineering will differ from a course aimed at health sciences students. Nonetheless, even chemists with widely divergent research interests find establishing curriculum content for an introductory course relatively easy. However, for the most part, this is based on an assumption of a certain degree of pre-knowledge which can no longer be assumed.

Curriculum reform

This paper is focused on developing a philosophical foundation upon which a new curriculum for this course may be built. This is not the most obvious starting point for curriculum reform. Kern, Thomas and Hughes (2009) suggest that curriculum development comprises six phases: general situation analysis; evaluation of learner needs; formulation of goals and objectives; choice of educational strategies; implementation and evaluation; and feedback. The situational analysis reveals a problem to be addressed and the next three phases yield a proposed solution which is then implemented and evaluation. Evaluation then forms part of the situational analysis of the next cycle of improvement. Whilst this strategy is, no doubt, a very practical approach, it presumes that the intention of the curriculum is clearly known. Barnett and Coate (2005) argue that this cannot and should not be assumed. In essence, what is being suggested is that we begin to take cognisance of education praxis in the development of such a curriculum, and not simply education practice.

Given that the content of an introductory chemistry course is not usually controversial, putting the content front and centre as the starting point for discussing curriculum reform is not necessarily terribly helpful. In courses where the content is more contested, debate around what should be taught, may quickly develop into debate around what the intention of the course in terms of the overall development of the student. Part of the implicit function of courses in higher education is precisely to introduce students into the discourse of the subject (Barnett & Coate, 2005; Gee, 1996). However, in chemistry, when one starts with the course content the conversation quickly terminates. The debate may be prolonged productively if one begins to engage in questions of 'learning context' (Gilbert, 2006). But even this debate fails to ask examine which qualities are being developed in the student. In Barnett and Coate's terms the being of the student is overlooked (2005). We seem content to educate for 'competence' and abdicating all responsibility for educating for 'wise judgement' (Walker, 2006).

In Maton's terms (2000), chemistry has a strong knowledge code of legitimation. This means that it is easy to overlook the significance of the person involved in studying chemistry. It should make no difference whether the student comes from a top private school or has fought their way through a severely under-resourced township school, the chemistry remains constant. However, evidence shows that it is not quite so simple. The person of the student and their personal and pedagogical history have an impact on how they learn (Dewey, 1963; Rogers, 1983) and how they are able to engage with or are alienated from a particular set of pedagogical circumstances (Case, 2008; Mann, 2001). Curriculum in the way described by Kern and co-workers (2009) fails to address this side of education. Barnett has written extensively on the importance of knowing, acting and being in education (Barnett, 2000, 2004a, 2004b, 2008). In *Engaging the Curriculum in Higher Education* (2005), Barnett and Coate take up the task of tracking these three elements through the notion of curriculum. Whilst the knower is somehow alluded to as the one who acquires knowledge, and acting is hinted at through the development of skills, the notion of being is much harder to locate in the sciences. In the social sciences, and those knowledge areas which have a stronger knower code (Maton, 2000), the significance of being and becoming are far more readily seen. After all if that which is known is inextricably linked to the person who knows; then self-knowledge and self-reflection must be an integral part of the development of maturity. In areas which have a stronger knowledge code of legitimation it is very easy to overlook the importance of the person of the student. At the same time, it can also be difficult to argue for the importance of valuing the person of student because at first glance it appears irrelevant to the far more substantial task of developing skills of critical thinking and a robust knowledge base of the particular subject.

However, engaging in the language of 'being' or knowledge and knower codes of legitimation, do not serve one well when trying to broaden the conversation concerning the essence of a chemistry course. It is very hard to argue for the valuing of these intangible elements, when the primary drivers of curriculum reform are the eroding standards and the pressure to improve pass rates (Barnett & Coate, 2005). Giving status to personal development is quickly dismissed as being beyond the purview of a science curriculum. But if higher education is to be transformative, both in the social sense of promoting equality and in the individual sense of growth, then science cannot simply shrug and say 'it's not what we do'. One problem here, is that few academics from the 'hard sciences' (Becher & Trowler, 2001) engage in the conversation of the larger societal significance of higher education. The result is, that even when issues such as transformation are illustrated using such a hard science

(cf. Barnett & Coate, 2005), it often seems as though it has been tacked on rather than truly integrated, precisely because the author is not a member of the 'tribe' (Becher & Trowler, 2001). One way around this problem is to approach the curriculum through established and respected philosophies. Of course, the choice of philosophical foundation must be one which is recognised by the hard science tribe, and which allows access to the ideas of transformation. But again the goal is to establish a curriculum which is rooted in education praxis: the practice of education which is informed by theory and which is reflected upon.

Two giants of 20th century philosophy, John Dewey and Karl Popper, provide us with food for thought in this respect. Both Dewey and Popper have clear, but somewhat different, ideas for a well functioning society. For both Popper and Dewey, society requires engagement of the individual (Magee, 1974; Westbrook, 1993). This relies on the capacity of the individual to engage and thus requires a commitment to the development of critical thinking, reflection and agency. Whilst critical thinking and reflection are clearly valued by both, agency is not made explicit in the writings of either.

Dewey

Dewey explicitly links his ideas about progressive education to a well functioning democracy and highlights the importance of the past and future learning processes to any educative program (Westbrook, 1993). When one is teaching a course which is encountered in the first semester of the first year of university this perspective is important, and offers some support across the metaphorical 'gap'. Giving some thought to where the students have come from and what they are being prepared for is crucial. Dewey presents us with the sobering thought of a 'miseducative' process (Dewey, 1963). A miseducative experience is one which inhibits a person's ability to engage in further educative processes. This means that it is possible to teach in such a way that we diminish a person's curiosity. As a teacher of chemistry, I have witnessed the products of such a process. As a teacher of organic chemistry, a subject which is either loved or loathed, the manner of presentation is unquestionably crucial. The vast majority of first year students would not choose to do chemistry if the degree path they had chosen did not require chemistry. We begin with a mixed bag of students. The variance in ability, is dwarfed by the variance in terms of desire to learn and enthusiasm for chemistry. Perhaps the only way around this, is by daring to be passionate in the face of ambivalence and resistance; by choosing enthusiasm in the face of indifference. Nonetheless, at the same time, we must help the students to become aware of their own emotional response to the subject, and to work with that. Because whether they love chemistry or hate it, they still need to pass it. Dewey makes an explicit link between personal and intellectual development. 'Human beings are not normally divided into two parts, the one emotional and the other coldly intellectual—the one matter of fact, the other imaginative' (Dewey, 1933, p. 278). All too often though education itself fosters a split between the two (Dewey, 1933). To value intellectual development and to achieve intellectual development, one must pay sufficient attention to personal development (Dewey, 1963). For Dewey the purpose of education is the 'intellectual, moral and emotional growth of the individual and, consequently, the evolution of a democratic society' (Rodgers, 2002). Helping students to face their emotional response is part of their overall development.

This brings to the heart of Dewey's philosophy – the crucial role of reflection in the process of learning. It is through the process of reflection that we begin to make connections between what we already know, what we have experienced and the theory which has been presented to us. It is in this process of making connections that we begin to understand. The theory begins to have meaning. Reflection in Dewey's terms, is far more rigorous than simply 'giving pause for thought'. Reflection is a rational and systematic process which is usually precipitated by encountering a problem. The 'problem' includes anything from a real world problem, to noticing an incongruity with how one has understood a particular idea in the past and new information. The process of reflection usually passes through five phases: suggestions, problem, hypothesis, reasoning and testing. Reflection has a trajectory. Its purpose is to solve a problem or to make sense of something which is puzzling or confusing (Loughran, 1996).

There is one final element to reflection which is often overlooked. For Dewey, a crucial part of the 'testing' phase is to communicate one's finding. It is only when one tries to articulate or formally express one's thinking that one discovers the holes in one's logic. Many a university lecturer has commented on the experience that they only truly began to understand aspects of their subject when they began to teach it. In trying to communicate thoughts and ideas one is forced to probe them at greater depth. In so doing, often connections are made around which meaning begins to crystallize.

For Dewey there are three crucial attitudes which underpin successful reflection: open-mindedness; wholeheartedness and responsibility (Dewey, 1933). Open-mindedness speaks to a willingness to have one's ideas reshaped by new information and a degree of humility. Having one's ideas reshaped may require an admission that one has been wrong. Wholeheartedness speaks to the desire to learn. Responsibility speaks to the

commitment to taking action if reflection leads one to believe it is the appropriate response. In Barnett's terms, these attitudes invoke the being of person (Barnett, 2008).

Popper

Popper's views on education are far less explicit, but he adds two important elements which are implicit but less evident in Dewey's philosophy. If Dewey's focus on reflection provides us with the framework of the bridge between information and knowing, Popper provides us with the foundations at either end. Firstly, Popper argues that problem solving is a primal activity – a driving force for evolution (Miller, 1983). The principle problem to be solved in this sense is survival. For education this raises an interesting possibility – problem solving is an innate human quality. The role as educator is not so much to 'teach' problem solving as to provide an environment in which the innate problem solving ability of students is evoked. This is a wonderfully optimistic starting point. We do not have to create the conditions under which students will finally 'get' the process of solving problems. They inherently know how to do this, all we have to do is to help them to see how they can apply a skill they already have to a particular knowledge set.

Secondly, Popper believes that knowledge is only advanced through critique (Miller, 1983). Critique is not in individual activity. Critique must take place in the community. Dewey argues that the articulation of the product of reflection is the important final step in the process (Dewey, 1933). Popper's emphasis on critique that us one step further. In order to engage in critique some form of communication is necessary. But critique forces one to confront the weaknesses and flaws in one's reflection. A productive process of critique requires that one is able to hold one's hard won ideas fairly loosely. It is possible that even after expending much effort in the reflective process that one's conclusions are still not correct. It also requires that all, even the educator, recognise that however thoroughly an intellectual territory has been explored, there is always more to know. And further, that the knowledge which has not yet been revealed or discovered may change one's perspective of the entire territory. Perhaps the emergence of quantum theory in a discipline so convinced by Newtonian physics illustrates this point rather dramatically.

Implications for the curriculum

I have argued that the content of an introductory chemistry course is not usually a highly contested space. So, in many ways, debate over the content to be taught in such a course is unlikely to precipitate discussion over the real purpose of such a course. However, how such content is to be presented is more interesting, but still falls short of asking the bigger questions such as what is the purpose of higher education and how does this course contribute to that vision or conflict with it? To this end, I have presented some of the key ideas on the philosophies of Karl Popper and John Dewey. The question emerges – how do we provided a framework for scholarly reflection and a space for critique in an introductory chemistry course? It is probably worthwhile mentioning that such courses are almost inevitably taken by several hundred students and given in large lecture theatres.

Under similar circumstances in a pre-med physics course, Mazur and co-workers found the use of questions which probe conceptual understanding coupled with peer instruction a valuable tool (Crouch & Mazur, 2001; Fagen, C.A., & Mazur, 2002). This approach, sometimes referred at 'just in time teaching' (Prince & Felder, 2007), provides a useful and relatively non-threatening way for students to begin to give voice to what they actually think and understand. It naturally requires a level of reflection. The very process of articulation and formulation of sentences requires a degree of reflection. It also provides an environment where students are exposed to the thinking processes of their peers and in so doing can improve their own understanding, or be reassured that they do, in fact, understand.

Whilst peer instruction provides a natural framework for reflection, the periodic introduction of reflective questions to be answered in writing may also prove useful. The so-called 'minute paper' approach has been used in a variety of ways with great success (Angelo & Cross, 1993). However, most applications limit their scope to asking for a demonstration of knowledge, or noting areas of competence or confusion. The use questions which force students to think about possible connections such as, 'which other sections of chemistry did you find yourself thinking about during the lecture today?'; 'To fully understand the work we are doing at the moment, I most need to revise ....'; et cetera, may also be useful. The point here is to ask the student to make explicit the connections they may have already made implicitly, and in so doing to facilitate the process of meaning making. In addition, it may well prove valuable to ask questions which take cognisance of the more emotional aspects of learning, thereby, helping the students to establish an awareness of their emotional response and to reconnect this with their intellectual response.

It is worth recalling the three attitudes which Dewey (1933) requires for a productive process of reflection: open-mindedness, wholeheartedness and responsibility. Barnett and Coate (2005) situate the starting point for a valuing of the being of the student in the being of the academic. Likewise, if we are to try to encourage attitudes of open-mindedness, wholeheartedness and responsibility in students, we need to pay attention to the strength of these attitudes without ourselves. We cannot encourage an attitude of questioning and critique, if we are not open to the possibility that sooner or later, some dearly held misconception of our own may be revealed. We need to dare to be passionate in our teaching, and hold our responsibility appropriately. We are not responsible for the choices that students make; ultimately some will choose not engage. But we are responsible to ensuring that we provide an environment which is at least potentially educative for most of the students in the class. We are responsible for providing an environment which is engaging, rather than alienating (Mann, 2001), and in which the majority of students can develop intellectually and personally.

Finally, we need to begin to think about curricula in a fluid sense rather than a static one. It is unacceptable that courses can remain constant in the face of substantial changes in context and circumstances. We need to create a space of reflection and critique of the entire curriculum on an annual basis. These annual critiques will probably only require small incremental changes, but if the system is in place, we are unlikely to continue to function in such an absurd manner. We can therefore respond relatively quickly to changes in the school curriculum, and consequential changes in the conceptual understanding of those students who enter the system. The curriculum must be viewed as a dynamic and living entity which will be implemented slightly differently each year, at the very least because the people who are engaging with the curriculum change from year to year (Barnett & Coate, 2005).

Conclusion

It is imperative that we begin to truly examine the efficacy of our introductory courses in higher education. It is not sufficient to wring our hands and lament the eroding standards of the matric system. We are failing students just as badly as the school system if we fail to cognisance of the changing landscape. The particular course I have chosen to highlight here has been unresponsive to massive changes in the entry stage of students, the type of course which the students continue with, and the curricula of courses which the students take concurrently. In such circumstances, we would do well to deal the metaphorical plank in our eye rather than tinker with the splinter in the eye of the school system. Popper and Dewey between them provide us with a powerful imperative to create space for scholarly reflection and critique, set on a foundation of open-mindedness, wholeheartedness and responsibility. We need to hold this space for our chemistry students, but perhaps the only way we will truly begin to see the value of this, is if we dare to reflect upon and critique the curriculum itself on a regular basis.

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