INCREASING ACCESS TO HIGHER EDUCATION: REFLECTIONS ON A BORDER CROSSING CURRICULUM DESIGNED FOR AN ENRICHMENT PROGRAMME FOR TALENTED HIGH SCHOOL LEARNERS

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ABSTRACT
Curricula in programmes that aim to increase access to higher education for learners from disadvantaged communities often need to provide maximum benefit within a short contact period. With this in mind, a new subject, molecular literacy, was introduced into a residential enrichment programme for talented Grade 10–12 learners who attended for two weeks annually. This curriculum, which included concepts from different subject areas, was designed to encourage learners to think more broadly and outside the narrow confines of school subjects. The longitudinal progression of content knowledge was coherent; the cognitive demand increased each year; and learners were encouraged to question and think critically through the use of various pedagogies. In this article, the author argues that a constructed
subject area that crosses borders can, with careful curriculum design, play a valuable role in assisting learners to acquire the social and cultural capital to gain access to and succeed in the higher education environment.

**Keywords:** enrichment, epistemological access, cross-disciplinary curriculum, cultural capital, molecular literacy

**INTRODUCTION**

The Targeting Talented Programme (TTP) is a University of the Witwatersrand (Wits) outreach initiative which is now in its seventh year. The enrichment programme aims to increase the social and cultural capital of talented Grade 10–12 learners, mostly from disadvantaged communities, as well as to increase their access to higher education. The programme was initially implemented with a strong focus on mathematics and physical science. There are two clearly defined aims of the programme. The first is to offer support to learners for their school mathematics and science content and the second is to provide an enrichment component. Each year, learners have three contact periods. Two of these (during the April and September school vacations) cover the school mathematics and physical science content so that learners will be well prepared for their final Grade 12 school examinations, which are the gatekeepers of access to university, and the third (in the June vacation period) is a two-week residential programme at the university which provides the enrichment component. The curriculum of the programme has been designed to increase the learners’ social and cultural capital by providing them with a range of experiences and different ways of learning which are likely to support them in the higher education environment.

Bourdieu (1986) recognises and comments on three types of capital, namely: economic, cultural and social. With respect to cultural capital, which he had articulated previously (Bourdieu 1973), his main thesis posits that learners from privileged backgrounds acquire from their upbringing knowledge and skills that will enhance their chances of succeeding in a higher education environment which values such knowledge and skills. This might be as a result of input from their parents and the investment of their time in promoting the types of knowledge and skills that will subsequently ensure educational success. In this respect, cultural capital thus confers advantages in a particular social setting by being sought after in a system of exchange. Bourdieu (1986) also introduced the term ‘social capital’ to refer to the benefit of belonging to a group of a particular social class that confers advantages in terms of networking, resources acquired from group membership, as well as the benefits inherent in the group’s support. The relationships which occur from the resulting social stratification may be considered to become almost institutionalised in terms of their recognition and continuance. In fact, educational institutions may
help to ensure that the social and cultural ideals are maintained by rendering them far less accessible to those who do not possess the social and cultural capital of the dominant classes.

Slonimsky (1994) describes the concept of ‘educational disadvantage’ in a university setting as the disjuncture between the student’s internalised cultural context and the university environment which has not yet been internalised. While all students might struggle initially, those who do not possess the requisite social and cultural capital find it far more difficult to adjust to the university’s institutional culture and to succeed. Holtman, Marshall and Linder (2004) distinguish between formal access to a university and epistemological access. Although formal access might be easy to define since it focuses on issues around registration, funding and locality, epistemological access is more difficult to characterise in specific terms since it involves an understanding of the unwritten and unspoken rules and values which are part of the institutional culture. While many students gain formal access to higher education, a large majority, particularly those from disadvantaged communities, find it far more difficult to gain epistemological access. Therefore, curriculum design is extremely important in interventions such as the TTP. An overriding principle is that the curriculum should help learners to change their ways of thinking and learning practices to those which will promote easier access to the university culture.

Jackson (1992) outlines the disparate ideas implicit in the term ‘curriculum’, distinguishing definitions which imply that it refers only to organised school knowledge, from those which include the entire range of experiences and learning opportunities offered, as well as including the acknowledged possibilities for preparing students for future participation in society. The broader definition of the term also encompasses incidental learning and experiences, so that there is a ‘hidden curriculum’ within the explicit or formal curriculum. Activities that will promote epistemological access to university are likely to be located in the hidden curriculum. There is, however, also a need to recognise that it is possible to distinguish between the ‘intended’ and ‘enacted’ curriculum and that, going further, the concept of the ‘enacted curriculum’ can be refined to distinguish between what was delivered and what was experienced or received. This suggests that it is valuable to obtain learners’ responses after their exposure to the curriculum.

RATIONALE FOR DESIGNING THE MOLECULAR LITERACY CURRICULUM

In keeping with the aims of the enrichment aspect of the TTP, a subject called ‘molecular literacy’ was introduced into the two-week residential programme, along with language, computer science, information literacy, engineering, mathematics, physical science, social research, life skills, workshops on diversity, music, sport, and dance (hip-hop) and, more recently, humanities subjects such as philosophy, international relations and sociology. Molecular literacy was conceptualised as a
subject which would reflect a reorganisation of knowledge, from what Bernstein (1996) refers to as ‘singulars’ to a ‘region’. Thus, it incorporated principles from the so-called ‘singulars’ of physics, chemistry, biology, biochemistry and mathematics into a single newly conceptualised subject (‘region’) which the participants in the programme would not have previously encountered. This strategy was considered pertinent to an enrichment programme because the approach would encourage learners to think conceptually and more broadly across disciplines and thus outside the narrow confines of a school subject. From another perspective it was envisaged that the learners would be able to take back (and apply) the general principles and concepts they would be exposed to in this new subject, to the various disciplines from which it had been derived.

Drawing on Bernstein’s (1999) framework of different knowledge structures, in which he distinguishes between horizontal and vertical discourses, it was decided that as the disciplines from which the subject emerged could all be classified as vertical hierarchical discourses, the curriculum would be based on a progressive knowledge structure, which thus assumed that it would have a specific developmental trajectory. Theory in hierarchical knowledge structures develops through integration with existing knowledge which implies that attainment of hierarchical knowledge is best achieved when built up from first principles. However, even though vertical hierarchical knowledge systems lend themselves to systemic progression of acquisition, a list of topics of increasing complexity does not necessarily indicate the optimal learning path since it is often necessary to revisit content in another context and from another perspective. For purposes of instruction, re-contextualised knowledge domains must follow a logical sequence which is determined both by what knowledge the knower has acquired (Bernstein 1999) and, in terms of cognitive demands, what the knower is able to do. It was, therefore, deemed important to make sure that the learners had mastered the concepts before moving on and that they had the flexibility to refer to and to return to content that had been taught previously in the programme and in the high school curriculum.

With this in mind, when selecting curriculum content for the first year of the TTP, it was recognised that although the learners might have encountered some of the content knowledge previously within the school curriculum, it would now be taught in a new context. This strategy, which might intuitively seem contrary to the enrichment mandate of the programme, is nonetheless supported by the work of Craig (1996). She foregrounds the basic principles for cognitive change in terms of the conflict between familiar content and unfamiliar forms, and points out that even in vertical knowledge structures it is necessary to cover similar topics at different levels and in different forms and circumstances (Craig 1996). Therefore, in the context of the programme it was felt that even content which had previously been taught at school could be taught from a different perspective, using different pedagogy, and with increased cognitive demand. Moreover, since the learners would encounter the content as part of a different subject, it would be taught in a completely different
context with different applications, and at the faster pace usually only encountered in
a higher education context, all of which could improve the learners’ epistemological
access at university. Another issue to consider when designing the curriculum, was
that the learners would only be exposed to the subject for a short time during the
programme each year, which meant that they should derive maximum benefit in a
short period of time.

The choice of teaching a ‘contrived’ new subject which drew on content from
several disciplines taught at high school was in line with an aim of the TTP, namely,
to ‘increase the learner’s academic preparation for admission to and success at South
African selective universities’ and ‘to design and implement a residential academic
enrichment curriculum’. One of the most common problems that I encounter as a
university lecturer is that students are unable to cross boundaries and apply a concept
in a different circumstance from the one in which it was first encountered. To this end,
it was felt that it was essential to ensure that the learners understood the conceptual
underpinnings of the content knowledge base and that they should be able to apply
these under various conditions and in different contexts.

In addition, the proposed curriculum and pedagogy were viewed from the
perspective of Vygotsky’s (1978b) proposal that learning takes place in the ‘zone
of proximal development’ (ZPD) which he defined as the gap between what task a
learner is able to perform independently and what he/she is capable of performing
with assistance from an instructor. In light of this, it was essential to establish the
learners’ actual levels of development in specific conceptual and content domains.
The rationale was that, in terms of the ZPD, without obtaining this information,
further instruction founded on basic concepts would not be effective, especially in
subjects where conceptual knowledge is cumulative, since knowledge gaps would
severely hinder future learning. Therefore, despite the proposed progressive nature
of curricular content, it was deemed essential to retain the freedom to return to
content which had previously been taught at the schools and to revisit issues in
order to ensure that gaps were minimised and (ideally) eliminated. So, based on the
presumption that the effectiveness of instructional mediation would be dependent on
the learners’ actual level of cognitive development at the beginning of an instructional
process, instruction should effectively be based on the individual learners’ actual
level of conceptual development. The question then arose as to how to ascertain the
individual learners’ level of knowledge and conceptual understanding, especially as
a two-week contact period is too short to assess individual learners when they enter
the programme each year and then teach accordingly. To this end it was decided that
the enacted curriculum would use pedagogy that allowed the lecturers to establish
the individual learners’ actual level of development in each knowledge domain and
would support the development of greater understanding of the content.
PEDAGOGY

Interactive classroom response systems have been advocated as a means of enabling teachers to track individual learners’ understanding during instruction, and to enhance classroom interaction (Beatty et al. 2006). Therefore, it was decided to use the Interwrite PRS technology, which uses radio transmitter keypads (‘clickers’) and requires the insertion of questions into PowerPoint presentations. Individual responses are transmitted to a radio-receiver connected to the teacher’s computer, and the class’ results are projected onto a screen after each question so that everyone is able to view the class’ responses. This enables the teacher to respond appropriately and to pace the lesson to accommodate all the learners. The pedagogy is also useful for eliciting individual opinions and for encouraging class discussions which promote critical thinking and productive engagement (Brenner 2013). Learners may also be asked to make predictions based on their conceptual understanding so that misconceptions can be diagnosed. Moreover, from the point of view that learning is socially situated, interactive classroom response systems provide enhanced opportunities for learning if peer collaboration is encouraged when learners are asked to answer questions, so that the classroom may become a ‘community of practice’ (Lave 1993). The selection of this pedagogy for teaching molecular literacy had another advantage because of its requirement for questions to be inserted into PowerPoint presentations. Although there are arguments against PowerPoint presentations as a learning tool, in the context of the TTP it was considered advantageous since it was anticipated that most of the first intake of learners had come from disadvantaged communities, and they would not previously have had access to visual material which could explain scientific concepts.

The value of visual material is supported by Vygotsky (1978a) who proposed that tools, which are externally oriented, and signs, which have become internally positioned in the mind, are necessary for learning. Thus, visual aids may act as tools for learning abstract concepts, as they allow the brain to draw on embedded knowledge and thus access the signs which aid the learning of new concepts. The PowerPoint presentations, therefore, illustrated scientific concepts through the use of analogies to everyday knowledge to which the learners could relate. For example, the concept of electronegativity was explained using an illustration of two dogs having a ‘tug of war’ to demonstrate the greater attractive force for electrons of an atom with a higher electronegativity when it is attached to an atom with a lower value (see Figure 1).
Electronegativity

Refers to the ability of an atom to attract electrons

Figure 1:  PowerPoint slide used to demonstrate the concept of electronegativity

My longstanding experience as a lecturer of biochemistry has shown that the use of tools such as 3-D modelling can assist learners to understand molecular structures from a stereochemistry perspective. Many learners find it difficult to visualise the three-dimensional structure of the two-dimensional drawings of molecules that they encounter in their textbooks and often do not realise that molecular interactions are a consequence of the shapes of the molecules involved. Therefore, the construction of models was incorporated into the curriculum as an activity wherever appropriate, particularly as learners’ understanding of molecular structures relies to a large extent on making meaning from their ability to visualise what are essentially abstract structures.

Furthermore, since it was anticipated that most of the learners’ schools would not have laboratory facilities, it was decided that it would be important to include a practical component especially as working in a real, fully equipped laboratory would be an enriching experience for them. A further intention was that, as far as possible, the experiments would use chemicals which are obtainable from any store, so that learners could take the knowledge and protocols back into their communities and teach their peers. Nevertheless, I felt that while the chemicals might be common kitchen ingredients, the learners should use real laboratory equipment to increase their cultural capital. Since this would be a completely new experience, peer tutors, who were third-year biochemistry major students, were enlisted to assist at laboratory
sessions so that they could demonstrate and teach learners in small groups. This situation provided another opportunity to ensure that individuals would be taught at a level within the ZPD in a relaxed social setting. I also felt that the relationships and connections formed with the peer tutors who were currently at university would enhance their social capital.

Two skills required of university students are comprehension of published literature and communication in writing. By drawing on the ‘technological tool’ of language, writing forces the organisation of ideas, which is what seems to constitute ‘knowing’. In addition, writing is difficult to achieve purely through mimicry. Furthermore, it has been acknowledged that novices and experts in a particular discourse differ in the way in which they are able to organise concepts and knowledge (Beatty et al. 2006). Thus, writing could be used as a tool which provides the opportunity for organising newly acquired knowledge. For these reasons it was deemed important to include writing tasks in as many of the lessons as possible and to seek synergy with the language component of the programme. Thus, the critical engagement through writing (CEW) pedagogy (Brenner and Nichols 2013) was also applied in the enacted curriculum and formed an important aspect of the molecular literacy curriculum. CEW is based on the premise that students should learn to write and think in the discipline. It involves the inclusion of informal, speculative writing in class as well as more formal written assignments. It primarily supports the view that knowledge is dialogic and contentious and aims to change the students’ view of knowledge (particularly in science) as an uncontested body of facts.

Finally, it was decided that learners would be supported by providing them with comprehensive notes on the material covered, so that they could refer to these quickly and easily during lessons and not be required to write down content during the limited contact time available. Apart from other more formal writing tasks, the handouts also required the learners to write short answers and explanations to questions which were designed to promote critical thinking.

THE INTENDED AND ENACTED MOLECULAR LITERACY CURRICULUM

In the first year of the TTP, there was an intake of 296 Grade 10 learners who attended the programme for the following two years as they progressed through grades 11 and 12. The following cohort of learners, however, consisted of Grade 10 learners in the first year, grades 10 and 11 the following year, and grades 10, 11 and 12 the year thereafter (with each year accepting a new intake of Grade 10 learners). Subsequently, this has been the format of the programme so that it now caters for all three grades concurrently every year and catered for over 1 000 learners in 2014. This has impacted on the curriculum. For example, in the first year of the programme, there were ten one-hour sessions allocated to molecular literacy.
However, on reflection on the programme after that first year, it was decided that it would be more beneficial to have fewer but longer contact sessions, especially since the laboratory sessions required more time to perform experiments. In light of this, the ten contact hours were allocated to six sessions. This meant a rearrangement of the lesson material, but all the content was retained. Thus, the TTP now has a synergistic theme—‘Becoming’—and the focus of the molecular literacy curriculum content area is on ‘Becoming a molecular bioscientist’, that is, the patterns of learning and experimentation expected of practitioners in this profession.

In designing the Grade 10 intended molecular literacy curriculum and selecting the content for it, two of the aims were to build up a hierarchy of basic conceptual knowledge from first principles and to convey the idea that scientific knowledge is a way of explaining what has been observed. It was decided, therefore, that in this early stage of the programme there should be a substantial laboratory component as this would expose the learners to a different way of constructing knowledge and to the principle of obtaining information from experimentation which is central to the advancement of scientific knowledge. In addition, interpretation of experimental data requires critical reasoning and so this type of activity supports the mandate of the programme. Moreover, the experiments in the laboratory component of the curriculum were designed to complement the conceptual knowledge dealt with in the theory sessions. Nevertheless, in the design of the curriculum it was necessary to remain cognisant of the limited contact time (ten hours) allocated to the subject.

The theme of the Grade 10 molecular literacy component of the TTP was ‘Oil, water, sugar and salt’. All these substances comprised different combinations of only five of the chemical elements, namely, carbon, hydrogen, oxygen, sodium and chlorine. These elements (alone and in their various combinations) were used to teach and demonstrate the basic conceptual principles of atomic structure; how atoms bond to form molecules (including ionic, covalent, and hydrogen bonding); the stereochemistry of molecules; electronegativity; and polar and non-polar molecules and their properties. When studying atoms, learners were shown how in the molecular biosciences various models are proposed to fit observations. This was intended to shift their school understanding of science as a fixed body of knowledge to one of a changing dynamic subject in which knowledge is increasingly developed and changed in accordance with experimental evidence. Finally, a major writing component required learners to write an essay to develop an argument either for or against the use of bio-ethanol in the replacement of fossil fuels. The learners had read an article on the use of bio-ethanol prior to the writing session in the language component of the TTP, and they had engaged in a formal class debate on the value of bio-ethanol as a fuel during one of the language sessions. It was felt that this synergy would also model the border crossing required in learning. The learners were also made aware of the hierarchical nature of the content and the interconnections between various aspects of the material by the first and last slide of each of the PowerPoint...
presentations which depicted a ladder. In the first slide of each lesson, the material which had already been taught was listed at the bottom of the ladder, and the content to be covered during the lesson was placed at the top of the ladder. In the final slide of each lesson, the content covered in that lesson was listed with the material at the bottom to indicate that it had now been dealt with. Forwards and backwards referencing was frequently used to demonstrate how the concepts were related and interlinked, as well as to emphasise the principle of referring back to basic principles in order to access, understand and explain more difficult concepts.

Links to knowledge uncovered during laboratory sessions were made through informal discussions of the experiments during theory contact periods and by asking questions via the PRS technology. The earners were also encouraged to discuss their findings amongst themselves and with the peer teaching assistants of the practical component of the curriculum so that between them they could suggest explanations for the observations made in the laboratory. Feedback from the learners indicated that the laboratory sessions were a highlight of the curriculum and it was decided that they should be included in future years. It was also obvious to the lecturers that it had been a good idea to use peer teaching assistants since the learners were comfortable asking questions in the small groups. Also, because many of the teaching assistants had themselves come from disadvantaged communities, the learners had identified with them. Moreover, they quickly established connections and exchanged email addresses and mobile numbers with the peer teaching assistants, who were then in their third year at the university. It was felt that this increased the learners’ social capital, especially since most of the selected peer teaching assistants intended continuing with postgraduate study and so would still be at university when the learners entered first year.

In the second year of the TTP, synergy was created throughout the enrichment programme subjects by focusing all curricula around a central theme, ‘The bicycle’. Molecular literacy used the concept of ‘bi’-cycling and thus the curriculum reflected on the central theme from two aspects, each lasting for one week. The first week examined the materials used to design a bicycle from chemical and physical perspectives; while the second week was devoted to the biological aspects related to the fuel and metabolic pathways that provide the energy to cycle. A laboratory component was included in the second week. Thus, the first week included content related to the physical properties of materials; chemical aspects of elements present in materials that can be used to make bicycles; and the way in which various elements and molecules can be put together to make materials like alloys which are stronger than their individual components. Despite selecting curriculum content which would be synergistic with the overall theme, care was taken to select content which would build on what had been taught in Grade 10. From this perspective, the second lesson reviewed the atomic structure of carbon as well as the periodic table and Aufbau diagrams, and then built on these concepts to consider other elements which were
present in materials from which bicycles could be constructed. This was followed by an overview of the structure of metals which focused on the conceptual underpinnings of metal ion association and crystal structure. Back referencing was made to lesson 1 which had looked at the physical properties of materials. Chemical standpoints were used to explain why certain materials would have less tensile strength than others and why some would fracture more easily. In this way, the learners were made aware of structure/function relationships, and they were also required to make informed decisions about which materials to select for various applications in order to promote critical thinking. The third lesson built on previous concepts by looking at the advantages of combining materials to improve their properties. Once again back referencing was made to carbon (first introduced in Grade 10) when the structures of polymers and carbon fibre and graphite were taught and to metal structures when dealing with the structure of alloys.

In the second week, the curriculum covered diet, metabolism of food to provide energy for a cyclist, and a laboratory session to measure the amount of CO₂ produced during anaerobic respiration. In subsequent years this laboratory session was changed to a titration which required learners to determine practically the concentration of an acid. Furthermore, as the TTP has progressed to its current status with the overarching theme, ‘Becoming’, the Grade 11 curriculum content has been refined and continues to be developed and has changed its emphasis to offer even greater continuity with and longitudinal progression from the Grade 10 curriculum. Therefore, since the focus of the Grade 10 curriculum was ‘How molecules are formed’, the Grade 11 curriculum now focuses on ‘How atoms and molecules are used’. The biological aspects have been replaced by the theory and use of radioactivity. The Grade 11 curriculum thus includes content which would not previously have been encountered at school but which uses concepts that arose from the Grade 10 molecular literacy curriculum and which additionally could serve to demonstrate and teach other underlying conceptual principles from school subjects and give learners the skills to learn related material more easily in the Grade 12 school syllabus. In response to the learners’ poor graphing skills which had been noticed in the previous year, many opportunities were provided for graphical interpretation during class and the final laboratory session in Grade 11 also required learners to construct a graph from their experimental data. They were supported in this enterprise by the teaching assistants who once again were drawn from third-year university students. Reflection on the current Grade 11 curriculum suggested that learners would benefit from a second laboratory session and that the theory and use of radioactivity could be covered in one lesson instead of two. These changes were implemented in 2014.

The Grade 12 molecular literacy curriculum was initially conceived around the central TTP theme of ‘Questions’. In order to introduce the concept of inquiry-based pedagogy, the theme in molecular literacy was ‘Answering questions by asking questions’. Once again each group was given ten hours of contact time allocated
equally to six sessions. Every session was designed to have some type of practical component or activity and to have a selection of practice questions. The learners were supplied with microchemistry kits at the start of the programme so that the classroom could be used to perform laboratory experiments. It was felt that this approach would be preferable to one where time would be allocated to one laboratory session only, because it would mean that more experiments could be performed. Further, the learners could take the kits home and use them to review and perform experiments with their classmates. It emerged that the majority of the learners had previously only come across a description of experiments and had not had access to equipment and chemicals. From the enrichment aspect, it was considered that actually doing the experiments, and observing and explaining the results would counteract rote learning of content and would demonstrate actual scientific practice. Moreover, it was anticipated that it would make the content more meaningful. In subsequent years the Grade 12 curriculum has been modified to also include one formal laboratory session. Because university science courses often assume that students have been exposed to at least some practical sessions at school, it was felt that this strategy would be valuable in increasing their cultural capital.

To reinforce the central theme, all of the lesson material in the handout notes was structured so that an ‘inquiry’ procedure could be conducted. It was felt that using the inquiry-based approach for the TTP learners would demonstrate the usefulness of inquiry and would imply that any general or broad question may be answered by breaking it down and by asking and then answering more specific questions. It was emphasised during the initial contact period that this approach could be used when answering questions in the upcoming final school examinations and that it would be very helpful to be able to use this approach at university. The rationale for this assumption resulted from my observations with university students. When I introduced the inquiry pedagogy (MacMaster’s University) to my second year basic molecular sciences class in 2006, the response was overwhelmingly positive and one of the outstanding comments from students when an evaluation was undertaken, was that many were using this approach to understand all their courses. The ‘Inquiry’ theme has continued with the synergistic theme, ‘Becoming’, because inquiry is so crucial to the way in which molecular bioscientists work.

The approach to the Grade 12 curriculum content selection differed from that used in grades 10 and 11, since two-thirds of the content covered in molecular literacy was specifically selected from the material which covered the chemical aspects of the matriculation physical sciences curriculum. The content included was based on the areas that, after consultation with several tutors who give extra lessons to matriculation students, were perceived by most learners to be the most difficult to understand. The content was also chosen because it covered the underpinning principles for conceptual understanding of how reactions occur and it was felt that if learners were to master it during the TTP they would be prepared for independent
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study of the rest of the chemistry school syllabus from school textbooks. The rationale for using this approach was that it was anticipated that the learners in the programme would be concerned about their upcoming examinations, particularly as admission to a selected South African university would depend on their results. It was agreed by the programme coordinators that they would need support in their school subjects and so the model for selection of course content was partially one of supplementation. However, since the material was being taught using different pedagogy based mainly on experimentation and was delivered at a much faster pace, which was similar to what they would encounter at university, it was considered that the approach was still consistent with the enrichment mandate of the programme and would increase the cultural capital of the learners. The majority of the content focused on how reactions occur and the questions asked are shown below:

- Question 1: How do chemical reactions occur?
- Question 2: What factors affect the equilibrium of a chemical reaction?
- Question 3: What are redox reactions?
- Question 4: How do reactions take place in the body?
- Question 5: What effect does substrate concentration have on enzymatic reactions?
- Question 6: How do I report my experimental results?

On the other hand, some of the content, which answered question 4, was drawn from biochemistry (which is not experienced as a separate subject per se at school) meaning that once again the content selected was cross-disciplinary. It was intended that this approach would reinforce the principle that knowledge is not constrained by specific school subjects, but that conceptual principles may be applied to and are relevant in many fields. Also, the ‘Biochemistry’ component in the school biology syllabus is small and is covered very superficially, whereas here learners were taught about protein structure and enzyme catalysed reactions in more detail. Another advantage of including these content areas was that the molecular literacy lecturers are protein biochemists, which meant that they could present the material with authority and relate some of their research to the learners. Because the lessons were fast-paced, and because many of the practical components were undertaken in the classroom, third-year biochemistry students were used as teaching assistants during all the sessions. This meant that the learners could ask them to re-explain concepts they had not understood during the general part of the lesson; could be shown how to perform the experiments; and be made aware of the theoretical concepts that the experiments were demonstrating.
THE EXPERIENCED MOLECULAR LITERACY CURRICULUM

The experienced molecular literacy curriculum ‘consists of those events experienced by a particular student, by a set of students, or by the preponderance of students in a classroom’ (Barone 1980). While the main focus of the article has been to describe the molecular literacy curriculum and discuss the rationale for its design, it is nevertheless important to reflect on how the intended curriculum was experienced, especially since the learners’ role should not be underestimated. Therefore, although there was no true research focus on evaluating the molecular literacy curriculum per se, the learners were asked to fill in evaluation sheets at the end of the TTP each year. These required them to reflect on the curricula of the various subjects offered during that year. In the first year of the programme, the learners were asked to fill out evaluation sheets during the last session of molecular literacy. Most (95%) of the learners commented that they had understood the content covered. and had been able to list the concepts they had been exposed to. In an open question that called for comments, they indicated that they had enjoyed using the ‘clickers’, as the system had made it easy for them to engage with the material as it was taught. Further, the anonymity offered by the system had afforded them the opportunity to answer questions posed in class in a non-threatening way and thus participate fully in the lessons. In the language component of the TTP, the learners were encouraged to write letters about the other subjects to their tutors. Although this writing was not part of the systematic evaluation, one comment in a letter put it clearly:

I enjoy all the subjects especially molecular literacy because we use clickers to answer questions which means that even if your answer is right or wrong you won’t be exposed.

In light of this sentiment, a decision was taken to retain the pedagogy as the learners progressed through the programme. It also made the lecturers sensitive to the fact that being asked to answer a question individually and to justify the answer in front of new classmates could be intimidating for the learners at this early stage in the programme as this was obviously different from the approach used at their schools. Being requested to answer questions which did not entail class recitation of memorised definitions, but instead involved critical thinking and discussion (and sometimes dissention), appeared to be a new experience for most learners. However, after some initial shyness and with much encouragement, they appeared to enjoy the engagement and started voicing their own opinions and asking questions of the lecturers. Interestingly, the learners’ responses to the first question asked in class suggested that their previous educational experiences had required them to answer questions as a class by reciting knowledge. This response initially took the lecturers by surprise especially as the learners had come from different schools in different provinces; however, it did emphasise that the approach taken in the molecular literacy curriculum was an entirely new experience for them.
The PRS pedagogy has been useful in determining learners’ misconceptions and prior knowledge. An indication of how the Grade 11 opening PRS question, which required the learners to predict the properties they would want in a racing bicycle, was able to generate discussion and critical thinking is evident from the responses obtained from each group (Figure 2). It must also be emphasised that although the learners identified with the bicycle as a mode of transport, very few learners actually possessed one. None of the learners were aware of the desirable properties of a racing bicycle which meant that this question could be considered generative, in that the learners would not have been privy to information which would have allowed them to answer using prior knowledge. Generative questions have been defined as those which ‘confront children with phenomena about which they do not have any direct experience and about which they have not yet received any explicit instruction’ (Vosniadou 1994, 50). It is this type of question which holds the potential for understanding the mental model which a learner has held in order to answer the question.

![Image](Figure 2: Opening ‘generative’ question and responses from lesson 1 in the Grade 11 molecular literacy curriculum)

It is evident from the response chart that the majority (65%) of the learners in that class had thought that a racing bicycle should be light but flexible. On probing why,
it emerged that they had reasoned that a flexible bicycle would allow them to go round corners faster. This response obviously provoked discussions about forces, how a bicycle turns, and why a stiff frame would enable the rider to use his/her effort when pedalling to move faster. This example is indicative of the way in which a PRS question was used to promote critical reasoning and to provide insight into the learner’s mental model about how vehicles turn.

Other questions posed in the first lesson demonstrated that this method of formative and diagnostic assessment was a successful indicator of whether the learners were grasping the principles and concepts as they were taught. The immediate feedback to the class, which is a feature of the technology, allowed the teacher to deal with misconceptions immediately. For example, when it was evident that 24 per cent of the learners in the class were not clear about what tensile stress was after they had first been introduced to the concept, the teacher could then re-explain this concept to ensure that all the learners were keeping up with the material.

In Grade 12, the PRS ‘clicker’ question-based pedagogy was also found to be useful in determining the learners’ actual levels of development in specific domains as well as in determining the misconceptions the learners had brought with them. As a substantial component of the content had been drawn directly from the school syllabus, the learners were able to verbalise some of the content before it was covered in the lesson. However, PRS questions ascertained that even when, at face value, the learners appeared to understand the content, many were often unable to apply it in order to answer questions. Moreover, another advantage of the PRS technology was that it also created awareness in the learners themselves that specific areas still needed mastery.

The technology also revealed that several learners were still unable to read information from a graph which, in this instance, depicted an energy activation curve. Several of the PRS questions had been sourced from past matriculation examination papers. This was done deliberately to expose the learners to the types of questions and to the language which would be used in the examination papers so that they would feel more confident when presented with similar questions in the matriculation examination. It was evident that not all the learners were able to apply their theoretical knowledge and time was therefore allocated to discussion of these questions to promote better understanding and applicative ability.

As mentioned previously, a decision had been made to present theoretical concepts using visual material in the form of PowerPoint slides. The learners responded well to this approach and to the ways in which abstract concepts had been linked to situations with which they were familiar and could relate to, and indicated informally that it had made some of the difficult concepts more accessible. For example, in subsequent years in the programme, the learners were able to recall and refer to the Grade 10 slide showing the two dogs pulling at a ball on a rope to illustrate the concept of electronegativity (see Figure 1). This supported the
supposition that the slide must have had an impact on them when they first saw it. Similarly, the learners responded positively to the way in which the structure of a methane molecule, with its concomitant conceptual issues of valency of the participating atoms, had been explained through enactment. Generally, gauging from their enthusiastic approach to their molecular literacy lessons, they seemed to enjoy the relatively informal atmosphere created in the classroom.

The interconnections between the various aspects were emphasised in the first two and the last slide of every lesson in each grade. At least one learner seemed to appreciate the way in which the subject had been organised since one of the comments on the evaluation sheet giving a reason for having enjoyed the subject was:

In molecular literacy every topic/lesson was very clearly defined.

Learners seemed to appreciate the fact that the curriculum content frequently referenced what occurred in life and nature:

With molit I knew how to combine chemistry with normal life.

They are my favourites because they make me know much better what’s happening around me. They also make me know things I wasn’t aware of.

It was gratifying to see that many learners indicated that they had enjoyed the subject. In fact, in the evaluation questionnaires asking the learners to comment on all the subjects that they had been exposed to during the residential programme, 129 Grade 11 learners had listed molecular literacy as one of their three most favourite subjects, with 45 indicating that it was their most favourite. In contrast, only 32 learners had included it in the group of their three least favourite subjects. Specifically, when asked to justify the rating afforded each subject, many of the learners seemed to have appreciated the fact that ‘thinking’ had been encouraged, and that some of the material had presented a challenge.

They require you to think differently in such a way that it improves your thinking ability.

I like subjects that are challenging and require me to think.

These comments were rewarding because they suggested that the learners had experienced the curriculum as I had intended in that it had been designed to make learners think critically and to transfer conceptual understanding across boundaries. By realising that everyday experiences could be explained from a molecular perspective and by thinking through issues from first principles, they were also thinking outside the narrow confines of their school subjects.

From the responses collected on the evaluation forms, it appeared that some Grade 12 learners were pleased that some of the curriculum content had supported and supplemented what they had (or should have, but had not) learnt at school:
I now have lot of knowledge about chemistry and I now enjoy it. I used to hate it because I did not understand before but the TTP lecturer did help me very much.

We don’t get to chemistry that much at school. I gain so much that I will help other Grade 12’s at my school.

The Grade 12 learners also seemed very grateful to have been given the opportunity to perform the experiments which they previously had only read about in their textbooks:

I now know the experiments that are done on the text book and I did them myself so I understood better with experiment.

It was, therefore, concluded that the use of microchemistry kits was a successful strategy which enabled the learners to perform the experiments in conjunction with the relevant theory. Also, the kits could be taken back to the learners’ communities. The small group learning strategy proved to be useful from more than just a teaching perspective. Firstly, it encouraged peer group participation and collaboration; secondly, it created a less threatening discussion forum for making scientific observations and for reporting and discussing experimental results; and thirdly, the teaching assistants formed the interface between the teachers and the learners.

REFLECTIONS ON THE MOLECULAR LITERACY CURRICULUM AS A COMPONENT OF THE TTP

It is felt that the curriculum content which had been selected complied with the enrichment mandate of the TTP. In addition, as discussed previously, the creation of a new subject which uses concepts underpinning some of the science subjects studied at school is an important aspect which brings it into line with the notion of enrichment and one with the potential to increase cultural capital and epistemological access. Moreover, the emphasis throughout the three years was on conceptual understanding. It was confirmed by the learners’ comments that this approach was different from what was expected of them at their schools, where it appeared that the memorisation of content was considered to be sufficient. The curriculum content progression was good, and allowed the teachers to make forwards and backwards referencing, both within each year and between years. This type of referencing aids organisation of ‘content stores’ and promotes conceptual understanding which meant that learners were empowered to take charge of their own further learning by using basic principles. It also gave them another way to look at how to learn and foregrounded the importance of thinking in the process of learning. The content for the first two years of the programme complied with the content enrichment model. However, although a substantial portion of the Grade 12 programme used the supplementation model, the different teaching approach, the pedagogy and the
experimental component made even the review of content previously taught at the schools an enriching experience.

The longitudinal progression of content knowledge was coherent, made explicit to the learners, and the cognitive demand increased every year. This is evidenced by the large amount of material covered in Grade 12 compared to that covered in Grade 10. However, the pedagogy provided scaffolding for learning through the use of PRS technology and through the small group teaching support offered by the peer teaching assistants. The pace of delivery every year was much faster than what learners would have encountered in their school environment, but it was felt that this would indicate to them that the lecturers were confident in their ability to cope with it. Also, by ensuring that there was sufficient support to enable mastery, it was envisaged that they would gain confidence and feel better prepared for tertiary education. The curriculum design for each subsequent year was influenced by observations made during the current year which enhanced opportunities for mastery and conceptual understanding.

At every opportunity the curriculum attempted to be synergistic with other components of the TTP. It was obvious to the lecturers and peer teaching assistants that the learners approached the laboratory components in all three years enthusiastically and, from the learners’ comments on the evaluation sheets, they were appreciated. Another strategy which proved to be useful was the construction of molecules. Because the learners are usually only exposed to molecules drawn in two dimensions in their textbooks, they are often unaware that molecules have three-dimensional shapes which are crucial to their functioning. The concept was therefore taught explicitly in the first year of the programme through the content which discussed stereochemistry of simple molecules and was built on in subsequent years by requiring learners to build models of crystal structures in Grade 11, and a globular protein molecule in Grade 12. The learners were also required to construct a model to illustrate the interaction of an enzyme and a substrate.

The PRS system was particularly effective in highlighting whether the learners had arrived with misconceptions derived from work taught earlier. For example, when asked to select the lightest material from a selection which had different densities, 30 per cent of the class selected the one with the highest density. This was concerning because this concept had been taught in the school syllabus and virtually all the learners could quote the formula which should be used to calculate density. However, some had obviously not thought about what the formula actually meant. This justified revisiting content which had already been taught at school from another perspective and in another context. It must be stressed that the approach throughout the molecular literacy component has been to encourage the learners to think about what they ‘know’ and to think about the conceptual underpinnings of what they have often memorised without doing so. This approach thus introduced a metacognitive aspect into the curriculum. From the comments and observations,
it was concluded that the curriculum had been responsive to the current and future needs of the learners in the programme.

One form of cultural responsiveness as it pertains to the curriculum assumes that teachers will respond to the cultural diversity of the students and society by offering alternative learning pathways for students (Moll 2004). Since the majority of the learners on the TTP had been taught by teachers who had been schooled during the apartheid era, they had been subjected to a very authoritarian approach in the classroom. Slonimsky and Shalem (2004, 81) point out that teachers trained in that era continue to teach with ‘deeply entrenched practices and orientations to knowledge’. This was evident in the learners’ recited response when they were asked if they knew what an atom was. However, the molecular literacy curriculum was designed to allow them to learn differently; they were encouraged to think critically and to ask questions. This way of learning is considered ideal in a university environment and, therefore, it was felt that prior exposure over three years would give them the cultural capital to succeed there.

Furthermore, at university, students are taught by lecturers who are motivated by research and who practice enquiry and contest knowledge (Moll 2004). This is often at odds with the students’ previous experiences of education. Therefore, exposure to a subject that has been designed to encourage them to cross subject borders, to think critically and to contest knowledge, as well as to allow them to learn through experimentation, would be more than just an enriching experience, but instead one that would provide them with the tools to access and succeed in the higher education environment. Moreover, the overarching approach in the Grade 12 curriculum was one of inquiry. From this point of view, I argue that the molecular literacy curriculum has been effective and a valuable part of the TTP.

In conclusion, from the molecular literacy perspective, the TTP has been very beneficial to the learners, and from the evidence gathered appears to have provided them with an enriching experience. Moreover, by using university lecturers as teachers in this subject, and university students as teaching assistants, the learners have been exposed to an entirely different pedagogic approach from what they were used to and, in fact, from what they would experience in any high school environment. This is likely to have increased their cultural capital which studies (Slonimsky and Shalem 2006) have shown to be so important for success in tertiary studies. Working within groups which are supported by peer volunteers has increased their social capital as well. From these perspectives, as well as the fact that the learners have been exposed to a subject which does not appear in schools, it is considered that the molecular literacy component of the TTP has increased the learners’ chances of success in future undertakings.

NOTE

1. Summary of Targeting Talent Programme Logic Model.
REFERENCES


