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Accommodating those Most at Risk. Responding to a Mismatch in Programme Selection Criteria and Foundation Biology Performance

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In South Africa, foundation programmes are a well-established alternative access route to tertiary science study for educationally disadvantaged students. Student access to, and performance in, one such foundation programme has been researched by the authors seeking opportunities to improve student retention. The biology module in particular has been recognised to place students at risk of failing the foundation programme, thereby reducing throughput into mainstream science programmes. This study uses decision tree analysis to provide a detailed description of foundation biology student performance so that points of weakness and opportunities for remedial action may be pinpointed. While students' alternative-entry selection scores have previously been found to most effectively account for performance in the programme as a whole, no similar positive relationship was identified for any subgroup of students in the foundation biology module. Conversely, academic language proficiency in the medium of instruction (English), formerly found to play no role in overall student performance, was revealed as primary in explaining achievement in foundation biology, most adversely affecting students rendered particularly vulnerable by an additional academic and/or socio-economic disadvantage. A pass in the stand-alone foundation academic literacy module did not necessarily correspond to a pass in biology. Compromised by educational disadvantage, compounded by a mismatch in programme selection criteria and inadequate academic literacy support, discipline-specific, fundamental literacy development in the biology curriculum is proposed to enable students towards epistemic access in the module. Pending this intervention, formal access to mainstream study is unlikely for the foundation students most at risk of failure.

Keywords: *Tertiary science access programme; Biology student performance; Programme selection criteria; Students at risk; Academic literacy development*

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Introduction

Foundation programmes have been at the forefront of educational change in South Africa, and continue to respond to the problems concerning the legacy of apartheid education, and the shortcomings of the post-apartheid schooling system(s) as highlighted by many authors (e.g. Clynick & Lee, 2004; Kloot, Case, & Marshall, 2008; Soudien, 2007). Specifically, science foundation programmes are a well-recognised alternative access route to mainstream science study for Black African[1] students in particular whose under-representation in the tertiary science-education sector has been of concern for some time (Scott, Yeld, & Hendry, 2007). Foundation students are typified by educational disadvantage, which in South Africa is associated with socio-economic disadvantage (as measured by parents' educational, occupational and economic achievements), family breakdown and inferior secondary schooling, and characterised by the challenges of second language learning (Rollnick, 2010).

One such foundation programme, its constructivist philosophy, pedagogy and reflexive principles of curriculum development have been described in some detail by Kirby and Dempster (2011). Students are only considered for entry into this foundation programme if they have come from disadvantaged schools[2] which are generally overcrowded and under-resourced (see Department of Education [DoE], 2006; Grussendorff, Booyse, & Burroughs, 2010). Of particular concern is the issue of many underqualified teachers who are not sufficiently prepared, or capable to effectively deliver the 'learner-centred and activity-based' outcomes-based National Senior Certificate (NSC) school curriculum[3] (Morrow, 2005/2007; Umalusi, 2009).

Foundation students do not meet formal entrance criteria for admission to mainstream science programmes, but are recognised to have academic potential by their performance in alternative-entry tests. On admission, students enrol in a year-long, holistic, composite programme comprising mathematics, chemistry, physical science and biology modules which aim to provide them with foundational cognitive and practical competencies, and content knowledge needed for epistemic access to mainstream science programmes they may enter once they have completed their access year. A stand-alone academic literacy development module, which aims to enculturate students into the language of science as described by Parkinson, Jackson, Kirkwood, and Padayachee (2007, 2008), must also be completed. This autonomous academic literacy module and a counselling component are integrated into the timetable of the foundation 'package', and further contribute to students acquiring flexible, transferable learning strategies, appropriate study habits and other life skills needed for success in mainstream.

The foundation programme of study (hereafter referred to as the Foundation Programme) is considered to be among the most reputable and successful of the science access programmes operating in South Africa; it is well regarded by those working in the area of academic development (AD) in the country (e.g. Kloot et al., 2008; Rollnick, 2010), and has been shown to make an important contribution to increasing Black African female participation in the sciences in particular (Downs, 2010).

However, the number of students proceeding from the Foundation Programme into mainstream programmes has been low, which is a concern for the university and staff teaching on the programme, and consequently the subject of research towards improving student performance (Kirby & Dempster, 2014). Kirby and Dempster (2015a) have shown that performance in the foundation biology module is routinely weaker than in the other science foundation modules, and suggest that it is this module that places students most at risk of failing the programme as a whole; since a pass in *all* modules is required for students to proceed into mainstream programmes at this particular university, the biology module is an obstacle to improving retention and throughput in tertiary science, and of Black Africans in particular.

The current research pays attention to the risks to student retention and persistence identified by Kirby and Dempster (2015a) in their attempt to generate a substantive grounded theory to explain foundation student performance at this particular university. Specifically, a deeper understanding of foundation biology performance is sought to expose points of particular student vulnerability and to reveal opportunities for remedial action in this module. This work is thus a contribution to the body of research focussed on improving South African access programme success which has placed this country at the international forefront of the area of access to tertiary level science (see Rollnick, 2010).

Student Selection, and Indicators for Success, in the Foundation Programme

There has never been a racial criterion for admission into the Foundation Programme, although the majority of students have tended to be Black African with far fewer Indian and Coloured students, and no White students, registering.

To qualify for consideration for entry to the Foundation Programme, students need to have completed their secondary schooling having studied mathematics, physical science and/or biology/life science or agricultural science. Being an alternative access programme, formal criteria for entry have always been low. Prior to the introduction of the common NSC (see note 3), written by secondary school leavers of all race groups for the first time in 2008, a minimum of 20 admission point scores (APS) in the Senior Certificate (SC) was a basic admission requirement; only 16 APS in the NSC are required for consideration into the programme. (Students seeking access directly to mainstream science programmes are required to have achieved 34 and 28 APS in the SC and NSC, respectively.) Mathematics and science APS requirements are also low; a minimum of a SG (see note 3) F in the former SC or level 2 in the new grade 12 exit examinations is needed (see Kirby & Dempster, 2014 for a detailed explanation of the specific admission requirements).

The additional, alternative-entry tests that prospective foundation students are required to write because they do not meet the formal criteria for admission to mainstream study are typical of the science and mathematical literacy tests used by most South African higher education institutions to inform admissions and placement, a consequence of the conflicting reports on the predictive validity of the school-leaving academic results (see Griesel, 2006; Umalusi, 2009). These in-house maths and science selection tests are aptitude-style, aimed at testing subject-related, problem-solving skills and insight, and not content knowledge. Prior to acceptance into the programme, a 'selection score' is calculated for each prospective student based on performance in these alternative-entry tests and school maths and science results (a composite value for these school results is referred to as an 'M score'). Those prospective students achieving a 'selection score' of over 52 are automatically accepted into the programme.

In addition, prospective students write a generic academic language proficiency test, the results of which are used, not for admission at this particular university, but for placement into the different streams of the academic literacy development module (Parkinson et al., 2007). This test, the Standardised Assessment Test for Access and Placement (SATAP)-English for Academic Purposes (see Scholtz & Allen-ile, 2007), like all similar academic literacy tests used in South Africa (Cliff & Yeld, 2006; Weideman, 2006) is a task-based language assessment and aims to establish whether students entering higher education are sufficiently prepared to respond to the academic reading, writing and thinking and reasoning demands required of tertiary study without relating to a subject or discipline bias. Specifically, such tests aim to assess preparedness to deal with the academic language demands of the medium of instruction, not first or second language per se (Cliff & Yeld, 2006; Scholtz & Allen-ile, 2007). Given that English and Afrikaans (to a less extent) are the dominant languages of teaching and learning at South African universities (Department of Higher Education and Training [DoHET], 2002), tests are only written in either of these two languages (Weideman, 2006).

Seeking to understand what factors facilitated student success in the Foundation Programme as a whole, Kirby and Dempster (2014) included students' formal APS, and alternative-entry and placement test scores described above, in addition to biographical and socio-economic information in a suite of possible explanatory variables to analyse the 2008 and 2009 foundation cohorts; notably, the two cohorts represented the changeover in schooling system, from the SC to the NSC (see note 3). The 'selection score' was identified as being most effective in distinguishing students who were able to achieve an overall pass mark of 50% or more from those who achieved lower overall average marks; this finding was consistent across both cohorts. Relative to the 'selection score', the 'M score' was considerably less effective in identifying students (and in particular those who had written the NSC) who had the potential to achieve a passing average across all the foundation modules. Conversely, the alternative-entry maths selection test results were found to have increased value in explaining NSC student performance specifically.

In terms of school history indicators, students' Grade 12 total APS, and APS for mathematics and biology/life sciences had little to no influence on their final average marks. Similarly, language proficiency in the medium of instruction, as gauged by students' performance in the SATAP-English, and their school English APS, was found to be inconsequential to overall performance in the programme.

Kirby and Dempster (2015b) have described similar trends in the foundation mathematics modules, with the 'selection score' (and specifically the maths test component) most effectively describing students' average marks in this module. The effect of (English) language proficiency on achievement was more pronounced than described for overall performance in the programme: in particular those students scoring higher SATAP-English results achieved very weak averages for the mathematics module in 2009, and isiZulu home-language learners were predicted to fail, had they achieved lower alternative-entry selection scores and not benefitted from on-campus accommodation.

The Foundation Biology Module

There are significant challenges to teaching and learning in the foundation biology module. On entering the programme, students have inadequate background knowledge in mathematics and natural history in particular (and therefore inadequate schemata which are central to the programme's constructivist philosophy and pedagogy) (Kirby & Dempster, 2011), and they lack practical experience of science, computer and library skills, their secondary schools having had no such facilities (see also Clynick & Lee, 2004).

The curriculum and pedagogical practice of the biology module are designed with the explicit intention of meeting the needs of foundation students. The principal objective of the highly scaffolded curriculum, arranged in a series of developmental units, is to support students to acquire knowledge and understanding of basic biological content, conceptual and practical knowledge, an appreciation of biological systems and an holistic understanding of biology with respect to the unified nature of science (Kirby & Dempster, 2011). Curricular content serves as a vehicle for learning, and learning tasks are designed to be as authentic as possible, thus presenting students with opportunities to engage with the practices as would an established academic. This development of scientific literacy (as students are encouraged to behave, think, read and write like biologists in the laboratory, lectures, tutorials and on fieldtrips) aims to mediate 'distantiation and appropriation', activities to encourage academic depth within a particular practice and a necessary response to the needs of under-prepared students specifically, as described by Slonimsky and Shalem (2006, p. 42). Learning in Foundation Biology is further supported through the close articulation of the theoretical and practical components which negotiates the application and transfer of practical and cognitive skills.

The module design also takes cognisance that the field of biology is not, in general, favourably viewed by Black African students in terms of career options (Downs, 2010). Consequently, registration for Foundation Biology is predominantly extrinsically motivated, resulting in a tendency towards student disinterest in the subject (Kirby & Downs, 2007). Furthermore, students' awareness and appreciation of science (and particularly biology) are limited as a result of little extracurricular exposure prior to university (see Parkinson, Jackson, Kirkwood, & Padayachee, 2008, 2007). Instructional goals related to improving attitudes, values and appreciation are thus set.

Morrow (2005/2007, p. 101) describes teaching as the practice of 'organising systematic learning', as central to the achievement of students' epistemic access to their studies. Despite all the efforts towards this end (as detailed by Kirby & Dempster, 2011, and briefly outlined here), learners continue to underachieve in this module.

Kirby and Dempster (2015a) allude to a possible reason fundamental to this underachievement. In the generation of substantive grounded theory to understand and explain student persistence in the Foundation Programme, these authors identified a conceptual relationship between 'risk' and academic language proficiency in the medium of instruction, peculiar to foundation biology performance, and called for opportunities to ameliorate the foundation biology curriculum and/or the selection processes (to specifically accommodate the biology module) to be explored. The former issue, pinpointing areas of particular vulnerability after admission, is advanced here; the next step in a series of papers by these authors.

Although a culture of entitlement to formal access is understandable (albeit not to be condoned) in a country with such an exclusionary past, epistemic access cannot be demanded (Morrow, 1994/2009). Learning to successfully participate in an academic discipline (gaining epistemological access that 'links them into a trans-cultural community', Morrow, 1994/2009, p. 84) is something only students can do themselves—but it is contingent on the necessary support structures being in place. Specifically, in an attempt towards establishing conditions for epistemic access in Foundation Biology, the issue of language proficiency needs detailed attention: its effect on the achievement of students (at risk on account of their pre-existing educational disadvantage, and further compromised in a module with apparently ill-fitting selection criteria), and consideration of remedial action.

In an attempt to particularise the effect of academic language proficiency on foundation biology performance of the 2008 and 2008 student cohorts, decision tree analysis has been employed. Given the unique instability of the transition to the NSC experienced by these two cohorts, the analysis presents the opportunity to examine variability within and between student groups that had experienced different schooling systems. Findings are considered in the context of national and international literature on language proficiency and additional language learning in academic contexts characterised by disadvantage, and academic literacy development.

Method

The 2008 foundation cohort had exited the secondary schooling system having written the SC; the majority (60%) of those completing their access year in 2009 had written the NSC examinations (see note 3). All, but two students in the two cohorts examined were Black African (see note 1). The home language of 4.2% of students was English, the language of learning and teaching in the Foundation Programme, and its parent university; 82.6% of the student body were first language (home) speakers of isiZulu.

The merits of employing the decision tree analysis (a non-parametric alternative to traditional quantitative research methods) to generate easily interpretable, hierarchical visual representations of student populations have been advanced by Kirby and Dempster (2015b). Specifically, to allow the intricacies (in particular, points of context-dependent student vulnerability) of the Foundation Programme student body to be exposed, classification and regression trees (CRTs) (see Breiman, Friedman, Olshen, & Stone, 1984) were generated.

Foundation biology performance was measured by 'average final mark' attained in the module and 'proceed decision' (categorical response variable of a 'pass' or 'fail'). The compendium of explanatory variables analysed included biographical data, indices of prior academic performance and information pertaining to socio-economic conditions during the access year; Kirby and Dempster (2014, p. 8) detail these potential indicators.

Biographical data (gender, home language and quintile (see note 2) of secondary school attended) and academic performance history were collated from the University Integrated Tertiary Software system and from the alternative-entry and placement database.

A distinction was made between those learners who wrote the SC and NSC exams. Calculations of APS for each Grade 12 subject and for total Grade 12 scores were made in line with university protocol. For 2009 foundation students who had written the SC, normalised APS, adjusted for the change in schooling system were also calculated (see Kirby & Dempster, 2014). Those foundation students who had achieved the higher entrance criteria (APS) necessary for admission to the University's advanced ('augmented') access stream were identified in the database.

Alternative-entry indices included scores achieved in the in-house maths and science selection tests, the 'M score', and the composite 'selection score', in addition to the SATAP-English placement scores. Students achieving 'selection scores' that afforded them automatic acceptance into the Foundation Programme were identified ('autoaccept' criterion).

Socio-economic data (accommodation and travel arrangements during the foundation year, and financial support) for 2008 were collated from questionnaires administered to students in class. For the 2009 cohort this information was collated from university Student Housing and Financial Aid office records (no travel data were available).

Data analysis rationale and protocol (as described below) followed Kirby and Dempster (2015b). Using the CRT-growing method option of the decision tree procedure available from IBM® SPSS® (IBM Corp, 2012), regression and classification trees were built by recursively dividing the student performance data into relatively homogenous, dichotomous subgroups (nodes).

In the generation of regression trees to depict the continuous outcome variable, 'average final mark', the least squared deviation measure of impurity (computed as the within-node variance, adjusted for frequency weights) was used to measure the extent to which a node represented a heterogeneous subset of students. The Gini impurity measure (which is based on the squared probability of membership for each category of the outcome variable, i.e. 'pass' or 'fail') was used to generate classification trees.

The foundation student body was first separated by either schooling system or cohort in a forced split at the root node (where separated by cohort, normalised APS for SC students in the 2009 foundation cohort were used, and assigned a lower influence value (see Kirby & Dempster, 2015b)).

As described by Kirby and Dempster (2015b), stopping rules can be specified a priori by the investigator to limit the size of a tree grown. Regression trees were grown to provide detailed illustrations of the effect of explanatory variables on student achievement and were therefore not pruned; in-depth observations were further afforded by stipulating low minimum-number of cases in parent and child nodes (10 and 2, respectively). Classification trees were grown to their full depth, and then, for the sake of parsimony to highlight dominant effects, automatically pruned to the smallest sub-trees with acceptable risk values.

The hierarchy of context-dependent explanatory variables revealed in the trees was examined with a view to identifying the various key factors influencing foundation biology performance of subgroups of students (as defined by the trees). Specifically, factors found to yield the greatest reduction in 'impurity' with respect to the outcome variable by splitting the upper most parent nodes in the tree (nodes 1 and 2, $i(t)$) were noted as primary to explaining overall variability in performance of each cohort—or entire student body as defined by schooling system. The different variables selected as best splitters (s^*) of each descendent child node were recorded; similarly as each resultant node was recursively partitioned in their capacity as parent nodes, the explanatory variables making each split were noted (see Kirby & Dempster, 2015b, p. 133).

In particular, the relationship between the variables making each successive split was carefully examined, their respective 'improvement scores' (in purity of the child nodes as a result of the action of each best splitter variable) ($\Delta i\ (s,t)$) noted and their effect on the increase in the dissimilarity in the values of the outcome variable compared.

Surrogates ($\tilde{s}$) for each best splitter were examined to gain insight into competing explanatory variables, thus eliciting the richness of the quantitative data (see Kirby & Dempster, 2015a).

This process (a detailed comparison of the variables selected to split the child nodes, relative to those found to effectively reduce heterogeneity in their respective parent nodes) continued until no further splits in each of the tree branches were observed.

The normalised importance scores for explanatory variables provided information on the relative importance of each variable to the overall construction of the trees generated (see Kirby & Dempster, 2015b). In addition, note was taken of the variables that were identified as having played no role in the generation of the trees.

Student Performance in the Foundation Biology Module

The key indicator that distinguished students who struggled with Foundation Biology from those who performed better was the test scores for academic literacy (Figure 1: SATAP-English score = 100% normalised importance; best splitter of first-order nodes 1 and 2, highest in the tree hierarchy after the forced initial split into the two cohorts). No viable surrogate was found to exist for the SATAP-English score in 2008; in 2009 the English APS were the only possible (but weak) substitute for this placement test (Δi, $\tilde{s} = 1.57$, $\lambda = .35$).

Moreover, the SATAP-English score was found to be the leading variable affecting the performance of those students who achieved lower Foundation Biology marks, having been identified by the regression tree as being at risk on account of some

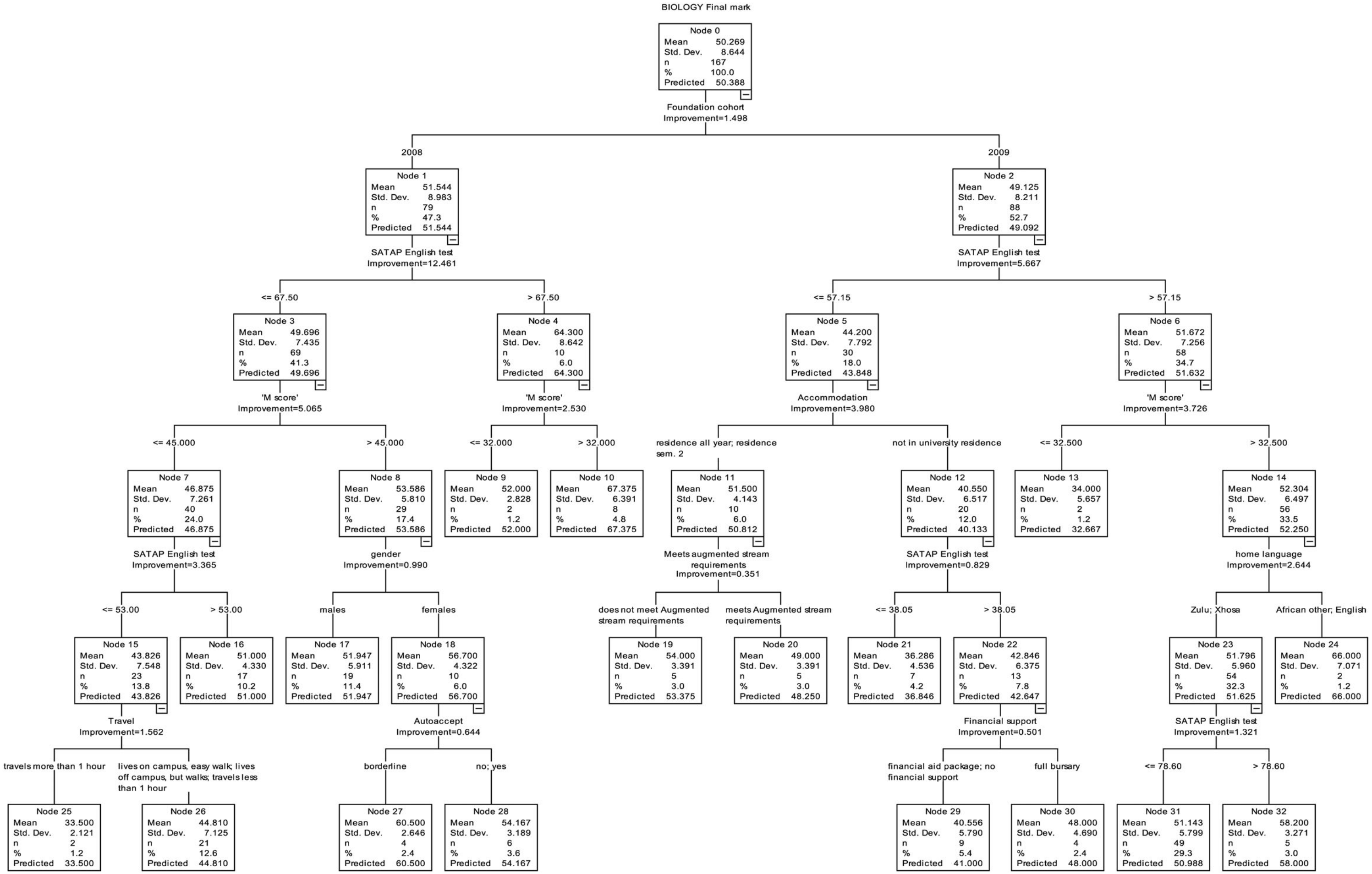

Figure 1. Regression tree for 2008 and 2009 final marks for foundation biology ($N = 167$) (not pruned).

other significant point of vulnerability ($M = 46.9\%$, 40.1% and 51.6%; see Figure 1, nodes 7, 12 and 23, respectively). Specifically, among those students scoring lower SATAP-English marks in each cohort (nodes 3 and 5), the performance of the 2008 students who had entered the programme with weaker school (SC) maths and science scores ('M score'), and the 2009 students who were not accommodated on campus was further influenced by issues related to their performance in this language proficiency test (nodes 15 and 16, 21 and 22). In these groups of particularly vulnerable, low-achieving students, only those with some added socio-economic advantage were able to improve their Foundation Biology marks (i.e. limited travel time or a full bursary, nodes 26 and 30, respectively). This negative influence of lower SATAP-English scores on the final biology mark was mitigated against if students were, in the second instance, advantaged in some other manner (higher 'M scores' in 2008 or on-campus accommodation in 2009) (node 8: $M = 53.59$, $SD = 5.81$ and node 11: $M = 51.50$, $SD = 4.14$, respectively).

In addition, among the better performing students in 2009 whose higher English-SATAP marks, and 'M scores' in the first and second instances, respectively, had effected a passing average (node 14: $M = 52.3$, $SD = 6.5$), lower SATAP-English achievement impacted negatively on South African students whose home language was not English (node 31).

It is acknowledged that, in addition to the variables tested, unknown factors will have affected student performance in the module (63% of the variability in the students' final biology marks is accounted for by the regression tree in Figure 1; risk estimate = 27.64). Of those variables investigated however, relative to the SATAP-English results, the formal and alternative-entry criteria employed to admit students to the programme were ineffective in selecting for optimal performance in Foundation Biology.

Neither students' overall grade 12 scores, their APS in the individual school maths and science subjects, nor their scores achieved in the maths and science selection tests were found to have an obvious influence on the final biology marks achieved in either cohort. The composite 'selection score' did not influence the performance of any subgroup of students.

Relative to the formal and alternative-entry selection indicators, the 'M score' was somewhat more effective in explaining student performance in 2008 (Figure 1, node 3: $\Delta i, s^* = 5.07$, $\Delta i = 0.69$, $\Delta i = 1.04$ for 'M score', overall grade 12 score and 'selection score', respectively). Although the 'M score' had some overall influence (as the second most important variable to tree construction, 44.5% normalised importance), its influence in 2009 was limited (node 13).

The inadequacy of the formal entrance criteria is reiterated in the splitting of nodes 18 and 11: automatic acceptance into the programme (node 28), or qualification for the advanced access stream (node 20), did not necessarily result in superior foundation biology performance.

These trends are refined in Figure 2 which splits the foundation student body according to the schooling system from which they qualified. The influence of performance in SC biology comes to the fore in 2008, suggesting that this subject was the dominant component of the 'M score' in Figure 1 (node 1: $\Delta i, s^*$ for Biology

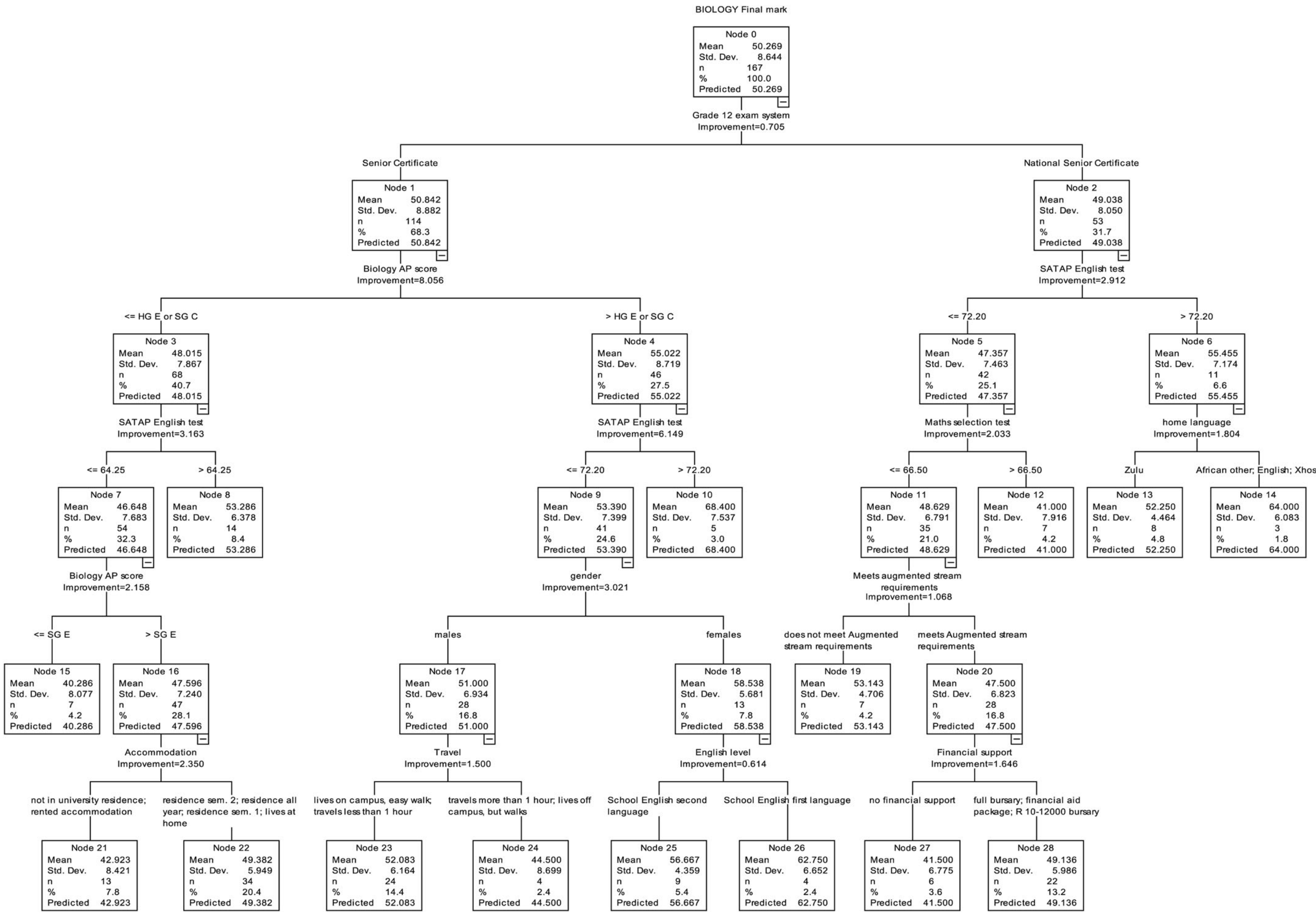

Figure 2. Regression tree for 2008 and 2009 final marks for foundation biology ($N = 167$), split by schooling system (not pruned).

APS = 8.06; Δi, $\tilde{s}$ for 'M Score' = 3.62, λ = .44) (Notably however, not all students had studied biology/life sciences at school and this was found to be irrelevant to performance as a whole: this variable was entirely absent from the regression trees). The reduced efficiency of the NSC 'M score' to explain foundation biology performance was confirmed by the absence of this variable as a best or surrogate splitter of all daughter nodes descending from node 2.

The disparity in alternative-entry selection criteria and performance in the biology module was also reiterated by the inverse effect of the maths selection test on some students' final biology marks (node 5, s^*), and the absence of the 'selection score' as a best or viable surrogate node splitter. Similarly, the inefficacy of formal admission requirements as foundation biology performance indicators was substantiated by the absence of overall Grade 12 scores in the tree, further illustrated by the subgroup of NSC students in particular, most of whom had achieved the higher entrance criteria necessary for admission to the advanced access stream, but who had, on average, failed the biology module (Figure 2, node 20).

While it is evident that, in the past, some students writing the SC exams may have benefitted from achieving well in biology at school, not only can this no longer be assumed if students have written the NSC (Biology APS was not a viable surrogate for the best splitters of nodes 2, 5 and 6), but it is apparent that academic language proficiency in the medium of instruction (as measured by the SATAP-English scores) is unmistakably more important on the whole than performance in school biology—or any other influence examined.

The SATAP-English variable, as best splitter of three high-order nodes (Figure 2, nodes 2–4), had considerably greater overall importance relative to the second most influential indicator of performance, Biology APS (100% and 49.5% normalised importance, respectively). English APS were similarly important to tree construction (47.1%), and the SC English APS was found to reduce heterogeneity in the daughter nodes of node 1 by only marginally less than the SC Biology APS (node 1: Δi, $\tilde{s}$ for English APS = 7.75, λ = .07).

For the NSC students (node 2), while it is evident that heterogeneity in the final biology mark might have been better explained by some other, unexamined variable, of those included in the analysis, factors relating to students' academic language proficiency (in English) were primary: the SATAP-English results, English APS and 'English level' (whether students had done English as a first (home) or second language was similarly effective in reducing the heterogeneity of node 2 (Δi = 2.91, 2.31, 2.61 for SATAP-English, English APS and 'English level', respectively)).

As identified in Figure 1, the positive influence of some socio-economic advantage on the performance of relatively vulnerable students is observed in Figure 2. Within the weaker subgroups of students from both schooling systems that exhibited a chance of passing the module (nodes 16, 17 and 20), some gain towards final average marks of 50% or more was achieved if accommodation, travel or financial conditions allowed for improvement (nodes 22, 23 and 28, respectively). The secondary influence of second-language-related challenges on some relatively higher achieving students was also reiterated (Figure 2, nodes 13 and 25, cf. Figure 1, node 23).

To explore the effect of the dominant factors revealed in Figures 1 and 2 on the achievement of a *pass* in the biology module, a pruned classification tree was generated using only the 'M score', factors related to language proficiency in the medium of instruction (i.e. SATAP-English scores, the English APS and 'English level') and socio-economic factors (accommodation, travel and financial arrangements) (Figure 3).

The SC English APS (node 1, *s**) were found to be a better indicator of academic language proficiency than those of the NSC (node 2). Irrespective of the indicator of language proficiency however, a number of students were, in the second instance, affected by accommodation arrangements (nodes 4 and 5, *s**); students who had written the NSC and achieved low SATAP-English scores were certain of failing the module, particularly if not accommodated in a university residence (node 11).

The reduced predictive efficacy of the NSC 'M score' is further clarified in Figure 3 (node 6, *s** cf. node 3, *s**). The model predicts that all NSC students achieving SATAP-English scores higher than 55.6 would pass this module irrespective of their 'M score' points (nodes 13 and 14).

Student marks in the stand-alone foundation academic literacy module are strongly associated with those achieved in Foundation Biology: ($r = .58$, $p < .0001$), this being a large effect size (Field, 2009); a regression tree generated for this module revealed that the first-order best splitters for the SC and NSC cohorts were also the SATAP-English results (100% normalised importance). Despite these associations, a comfortable pass in the academic literacy module for the majority of students (those who had written the SC) did not ensure a pass in Foundation Biology (Figure 4, nodes 3 and 4). Students who had written the NSC needed to have achieved more than average competency (above 57.5%) in the academic literacy module to pass the foundation biology module (node 6). Overall, 31% of the student body passed the academic literacy module, but failed foundation biology.

Discussion

A tension between access to, and success in, the foundation biology module and, by extension, the foundation programme as a whole has been clearly identified. Academic language proficiency in the medium of instruction, namely English in this particular institution, is primary in explaining performance in Foundation Biology: the alternative-entry selection criteria, however, do not include indicators of academic literacy—and nor should they. In terms of redress, and widening access to tertiary education to a greater number of educationally disadvantaged students—in South Africa, where the educational fallout of the hegemonic legacy of the English (and Afrikaans) language(s), distinctive of the country's apartheid history, persists (see e.g. Boughey, 2008; DoHET, 2002; Probyn, 2006; Weideman, 2013), to *select* students on the basis of their competence in a second language to meet the academic literacy demands of higher study would be patently contradictory.

Moreover, levels of academic literacy preparedness, relative to its primary effect on performance in Foundation Biology, were found to be inconsequential to performance in the other three foundation science modules (and in some instances, inversely related

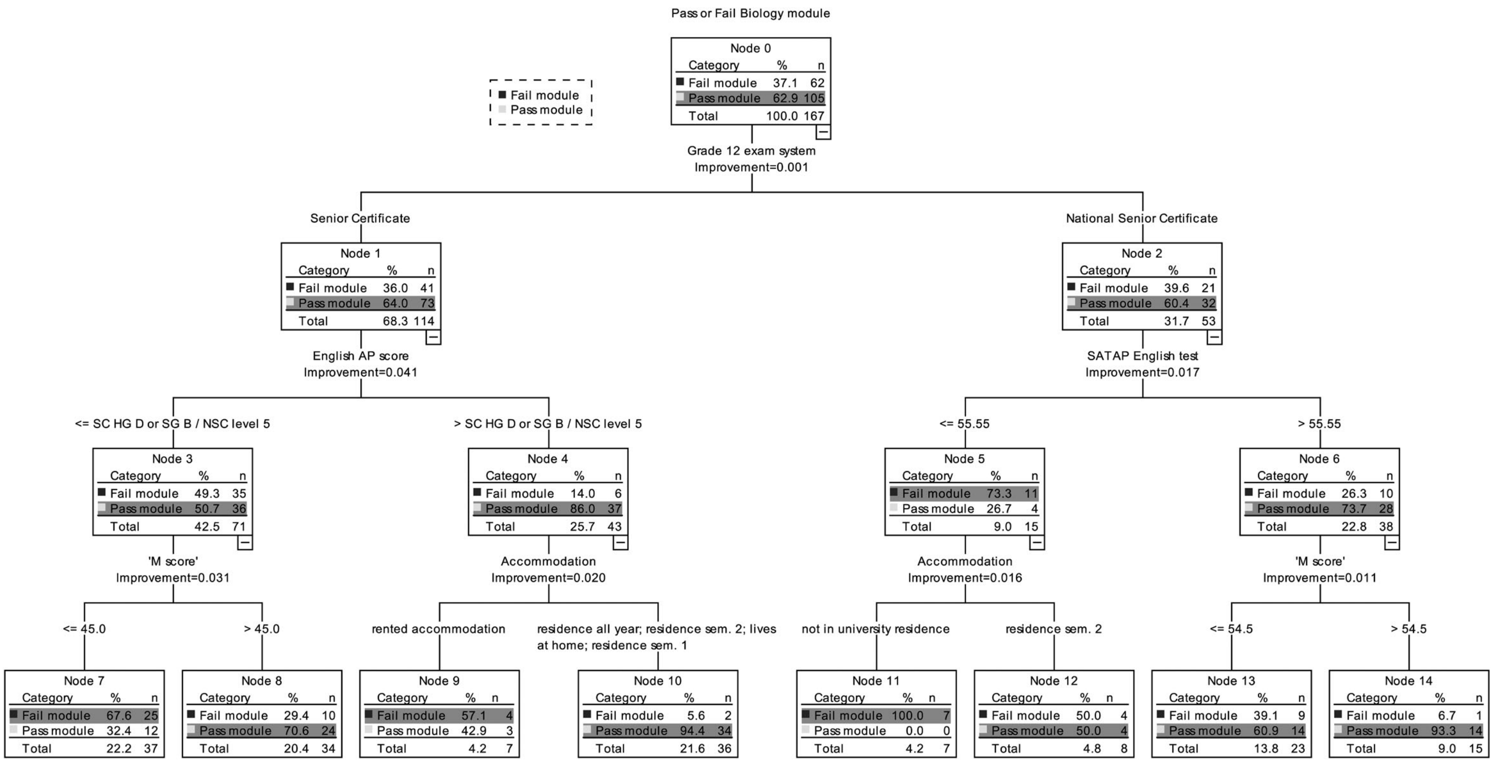

Figure 3. Classification tree for foundation biology ($N = 167$) to show the effect of dominant variables influencing student performance (category predicted by model indicated by dark grey band).

Note: Nodes 3 and 4: a SC D symbol (HG) was deemed equivalent to a (SG) B, and equated to a level 5 in the NSC (see Kirby & Dempster, 2014, p. 23)

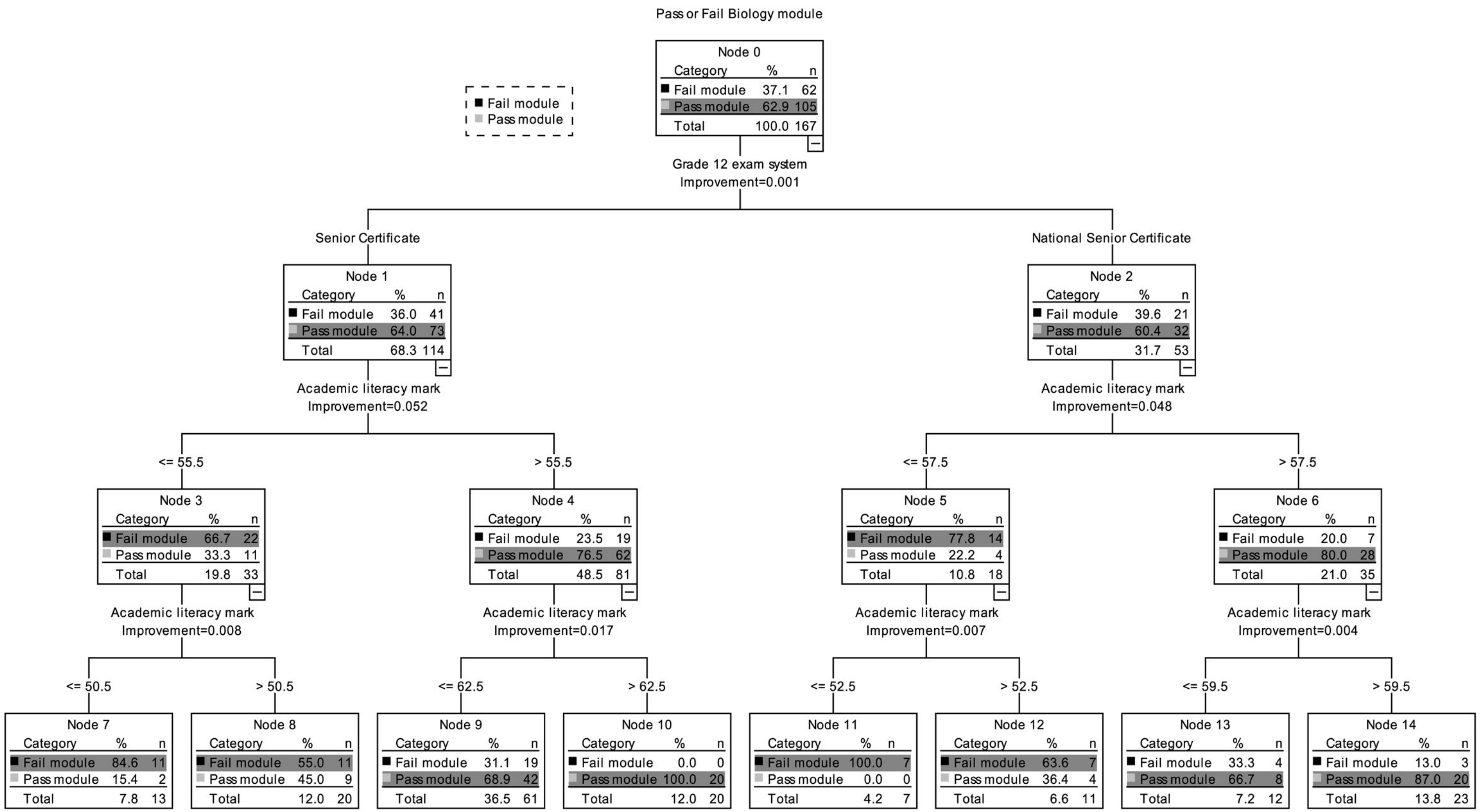

Figure 4. Classification tree for foundation biology ($N = 167$) to explore the effect of performance in the stand-alone foundation academic literacy module.

to achievement in them) (Kirby & Dempster, 2015a, 2015b): why so? And, academic language proficiency may not necessarily have been found to exert such a dominant influence on foundation biology performance had a disparity in selection criteria and achievement in this module not existed. Such questions and speculation will persist until an examination of the academic literacy demands of both the curricula of foundation chemistry, physics and mathematics modules and the in-house selection tests, respectively, are examined.

It has however become clear that not only have formal admission (school-performance-related) criteria been inadequate in selecting for optimal performance in Foundation Biology, but the alternative-entry criteria have also been entirely ineffective in selecting for academic potential in the module (i.e. for all subgroups of students, irrespective of whether the challenges to their performance have been alleviated by some academic or socio-economic advantage or not). The transition to the NCS school curriculum has not influenced this situation in any positive way: in addition to diminished predictive efficacy of NSC 'M score' relative to that of the former SC examinations, the biology performance of some students entering the access programme with an NSC was impaired by higher maths selection test results.

Foundation students, who are, by definition disadvantaged, are thus further compromised in the biology module by a mismatch in determinants of achievement in the foundation programme as a whole (see also Kirby & Dempster, 2014). If the criteria for selection are not to change, academic literacy *within* the biology module, and not the programme in its entirety, needs careful consideration.

'Academic literacy', as understood in the context of contemporary AD in South African higher education, derives from an expanded (interactive) rather than a restrictive (skills-based), simple view of language (see Weideman, 2013); interventions to develop academic literacy are commonly informed by the social linguist Gee's (1990/2012) notion of discourse, and an understanding of literacy (literacies) as a set of social practices (Lea & Street, 1998, e.g. Boughey, 2008; Marshall & Case, 2010; Parkinson et al., 2007). To varying extents, academic literacy interventions have been integrated into university science programmes: some have been located within specific science-discipline modules (tending towards disciplinary literacy as described by Shanahan & Shanahan, 2008) (e.g. Marshall & Case, 2010); others have served to induct students into broader science-community discourse, and been taught by academic literacy and not science content specialists (Parkinson et al., 2007).

In the design of the Foundation Programme academic literacy module, Parkinson et al. (2007, p. 446) motivated for 'a separate course rather than integrating language and communication into existing science courses', and elected for a genre-based pedagogy that explicitly mediated access to the structural and linguistic requirements of common (scientific) academic genres for the English second language (ESL) foundation students. Using different editions of the SATAP-English assessment to measure the effectiveness of this stand-alone module, Parkinson et al. (2008) have reported some improvement in academic reading and writing for all proficiency groups of Foundation Programme students, but with those in the weakest group still not achieving literacy levels necessary for academic study. While these benefits to performance in the academic literacy module are not to be disputed, it has become evident that these gains are not necessarily translated to enhanced achievement in the foundation biology module. Those students who *enter* the programme with greater academic language proficiency in the medium of instruction are able to meet the academic literacy demands of the Foundation Biology module; those with limited competence at the start of their foundation year continue to experience these adverse initial effects which are compounded for those, most vulnerable, who experience further academic and/or socio-economic challenges. Prejudiced by insufficient academic literacy support, these students face triple jeopardy indeed.

Low levels of academic literacy, and specifically challenges related to the language of instruction and its effect on access to academic discourse (Boughey, 2002; Weideman, 2006), are well-recognised obstacles to retention and throughput rates within the South African higher education sector (Scott et al., 2007). Having moved beyond an era in tertiary education in the country that assumed a deficient view of students' (English) language proficiency as a so-called language problem (see Boughey, 2002, p. 295), attention has turned to finding ways to support students who not only have to acquire and develop the practices of academic discourse, but also have to engage and be proficient in a language additional to their first language to do so. As Nel and Müller (2010) note the 'transition which English second language (ESL) students need to make when using English as the language of learning in higher education is a matter of great concern in the South African higher education sector' (p. 635).

Although these second-language learning concerns are certainly not unique to South Africa (e.g. Cummins, 2000; Hyland, 2003; Murray, 2010; Rose, 2007), what sets South Africa apart is the nature of their political origins, the magnitude of the ramifications thereof and the fact that the majority of learners are affected (Boughey, 2008; Rollnick, 2000, 2010).

In particular, reading literacy has long been recognised to be a national problem, and a particular 'barrier to learning' in South Africa (Probyn, 2006; Pretorius, 2002, p. 87), as borne out in the exceptionally poor results that South African learners continue to achieve in benchmarking studies (e.g. Department of Basic Education [DBE], 2011; Howie, Van Staden, Tshele, Dowse, & Zimmerman, 2012). Weideman (2013, p. 12), while identifying 'reading ability' as the perpetual, primary challenge to tertiary student success (despite decades spent designing interventions), articulates the fundamental reasons for the failure of learners to read.

Foremost, among African home-language speakers, English is generally perceived to be the dominant language of access and power, within (and beyond) the educational arena (Probyn, 2006; Weideman, 2013). As a result, despite the promotion of 'additive bilingualism' (that proposes a strong role for home languages as a basis for the acquisition of additional languages) through South African education language policy (DoE, 1997a), the official Language of Learning and Teaching for the majority of rural and township primary schools in South Africa is English (Howie et al., 2012). With very limited exposure to English outside the classroom, oral language use at home and in the classroom taking place in vernacular (Probyn, 2006), and the academic tasks of reading, writing and assessment performed in English, learners cannot make the transition to effectively engage with the curriculum—in any language. Unable to develop their cognitive academic language proficiency (CALP) in their home language, the majority of students' ability 'to access, and have command of the oral and written academic registers of schooling' (see Cummins, 2000, p. 67) is limited from the start, and they are faced with the challenge of developing their CALP whilst learning through an unfamiliar, second language (Cliff & Yeld, 2006).

Reading is also severely limited in mother tongue (see Howie et al., 2012) since very few books in African languages exist (Weideman, 2006). Furthermore, formal reading instruction all but ceases in their fourth year of primary school when learners are expected to 'learn from reading' (Parkinson et al., 2007; Pretorius, 2002, p. 189).

There is consensus that the majority of South African primary school children 'in the main, can't read or write' (Fleisch, 2008, p. 7), setting in motion their delineation as failures in high school as they experience high 'frustration levels' and are left decoding text at the expense of comprehension (Pretorius, 2002, p. 171). These same students enter tertiary education with inadequate CALP to cope with the academic literacy demands of their studies as reflected in the results presented in this study by the primary influence of the (school) English AP and SATAP-English scores.

Indeed, the test specifications of the SATAP-English were, like similar forerunners of the current, widely used National Benchmark Test in academic literacy (see Griesel, 2006), based on Bachman and Palmer's (1996) focus on the knowledge and understanding of the organisational, functional and sociolinguistic aspects of the language of instruction, and also informed by Cummins' (2000) notion of CALP (Cliff & Yeld, 2006). According to Scholtz and Allen-ile (2007, p. 923), who have indicated that the SATAP-English is a reasonable predictor of academic success for first-year higher education students, the basic tenet of the test was to determine whether students are able to use English as a 'vehicle' for 'extracting and making meaning' from text typical of an academic context. Evidently, the SATAP-English constructs are consistent with academic literacy practices required for reading and writing in Foundation Biology (if perhaps not with those of the other foundation science modules)—in the sense ascribed by Lea and Street: academic literacy in higher education points to reading and writing within the different *disciplines* 'constitute the central process through which students learn new subjects and develop their knowledge' (1998, p 158).

Shanahan and Shanahan (2008) have pointed out how reading in particular is approached differently across disciplines depending on how each discipline creates, communicates and evaluates knowledge, and highlight how textual differences present unique, discipline-specific challenges to readers. These authors make a very clear case for 'disciplinary literacy', acknowledging the literacy practices distinctive of the specialised knowledge and abilities of each discipline, and identifying the need for advanced literacy instruction 'embedded within content-area classes' (Shanahan & Shanahan, 2008, p. 40).

Evidence exists for increasing commitment to finding ways to adopt a disciplinary literacy approach within South African AD programmes for students entering tertiary

Science; commonly the interventions draw from Gee's (1990/2012) sociocultural perspective of language in learning (e.g. Jacobs, 2007; Marshall & Case, 2010).

According to Gee (1990/2012, p. 35), Discourse 'big D' emphasises the values and ways of thinking, feeling, believing and acting that characterise a particular (scientific) discipline and can be used to identify oneself as a member of a socially meaningful group; discourse ('little d') refers to language in use (the reading and writing) and 'only occurs within specific practises and within specific genres in the service of specific purposes or content' (the 'big D'). From this perspective, learners need to learn to participate in a d/Discourse community; successful learning will involve acquiring the 'small d' discourse of the discipline as it is represented in text, for the purposes of taking on the 'big D' commitments.

Yore and Treagust (2006, p. 295), as they expound on the diversity of views on the role of language in science literacy, infer a synergy between Gee's notion of D/discourse and the derived and fundamental senses of science literacy of Norris and Phillips (2003). Indeed, the parallels in the perspectives are helpful in refining the literacy needs within the context of this study.

For Norris and Phillips (2003, p. 224), the 'derived sense' of science literacy refers to being learned in the substantive content of science; being knowledgeable of the nature of science, scientific inquiry and the unifying concepts of the science disciplines. Reading and writing (when the content is science) are the 'fundamental sense' of scientific literacy—because 'the main source of both the substantive content of science and of the interrelationships within it is accurate interpretation of science text' (p. 37): the derived sense is a derivative of the fundamental sense at the level of discipline-specific knowledgeability. Despite their centrality to science literacy however, both the texts that carry the scientific content and the interpretive capacities required to cope with them are neglected in science education. Instead, curricula tend to focus on substantive content and are dominated by inquiry-activity pedagogies that aim to serve a 'derived sense' science literacy learning agenda (Norris & Phillips, 2003; Yore & Treagust, 2006).

Shanahan and Shanahan (2008, pp.43–45) agree that 'disciplinary or technical' reading-related literacy practices ('sophisticated genres, specialised language conventions, disciplinary norms of precision and accuracy, and higher-level interpretive processes') are seldom explicitly taught. There is general agreement that traditionally science teachers have not seen reading as an important part of science education and have had little concern for text (Shanahan & Shanahan, 2008, Norris & Phillips, 2003; see also Wellington & Osborne, 2001).

However despite the lack of explicit teaching, the characteristics of science texts (such as nominalisation and high lexical density of technical words) make them hard to read (Wellington & Osborne, 2001). Furthermore, as understood in the 'fundamental sense' of science literacy, the notion of reading is expansive and requires the 'mastery of literate thought', which refers to the thinking that is involved when meaning is inferred from the read text, and integrated into existing knowledge (Norris & Phillips, 2003, p. 228). Moreover, according to Yore and Treagust (2006, p. 296), all learners of the fundamental sense of science literacy experience a 'three-language problem' (home, non-standard form of instructional language; instructional (school) language; science language). As Shanahan and Shanahan (2008) would argue, higher level 'disciplinary or technical' uses of reading-related literacy in the sciences are difficult for *any* learner to learn.

For second-language learners, often characterised by disadvantaged backgrounds, the disciplinary literacy learning challenges, and the consequent need for explicit instruction, are far greater than for those who are learning to participate in a science-discourse community in their first language (Hyland, 2003; Parkinson et al., 2007; Rollnick, 2000; Rose, 2005). From a second-language learning perspective, Cummins (2000, p. 71) is clear that ' … language and content will be acquired most successfully when students are challenged cognitively but provided with the contextual and linguistic support or scaffolds required for successful task completion'.

Viewed through a theoretical lens as described above, it has become evident that teaching and learning in the biology module (as envisaged by Norris & Phillips, 2003) have focussed on the derived sense of scientific literacy, and failed to sufficiently develop the 'small d' discourse practices needed by students to cope with the reading and writing demands of the foundation biology curriculum (and thus fallen short of effectively enabling student access to the 'big D' Discourse of foundation biology). Moreover, the generic, stand-alone academic literacy module has not sufficiently well served the disciplinary, fundamental literacy needs peculiar of Foundation Biology (see also Weideman, 2013). It is from this perspective that an argument is made for science literacy development (in the fundamental sense) to be embedded within the Foundation Biology module.

A reasonable starting point for disciplinary literacy development in Foundation Biology is the 'Learning to read, Reading to learn' strategy researched and employed by Rose and colleagues (e.g. Martin & Rose, 2005; Rose, 2007). Martin and Rose (2005) argue strongly that reading is at the core of teaching and learning, and consider the primary function of writing to be the reinforcement of knowledge acquired through reading, and the assessment of the acquisition thereof. In quoting Bernstein (1990, p. 53) ('beyond the book is the textbook, which is the crucial pedagogic medium and social relation'), Martin and Rose (2005, p. 253) stress that systematic approaches to teaching reading should be at the heart of any pedagogy. 'Scaffolding' is central to this particular literacy intervention: the influence of scaffolded learning cycles on ontogenesis is explicated (highly congruent with the underlying philosophy and pedagogical approach of the Foundation Biology curriculum as mentioned earlier); it recognises the 'phylogenetic' influences on the 'ontogenetic sequence' through which reading ability (should) develops in the school curriculum (Rose, 2007, p.47), and emphasises the need for the *explicit* instruction at each *stage* of reading development sequence, and in each *step* of the task-based scaffolded learning cycle in which reading development is facilitated (p. 48).

This is highly relevant in a context such as South Africa where the majority of learners, because of the systemic dysfunctionality in their secondary schooling (and an absence of a 'reading culture', see Pretorius, 2002, p. 190), do not progress through the reading development sequence, and who consequently cannot recognise, understand or reproduce the language patterns of text by the time they enter tertiary education. Additionally, the 'Learning to read, Reading to learn' strategy has demonstrated success in South African classrooms (Rose, 2005).

Lacking the primary prerequisite for tertiary study, that is, to be able to learn independently from reading (e.g. Weideman, 2013), Roses' literacy intervention provides opportunities to attend to the neglected fundamental sense of scientific literacy, and for the explicit instruction of the 'little d' discourse practices of foundation biology, much needed by the second-language learners as they learn to participate in the 'big D' Discourse of tertiary science studies.

In South African academic contexts, until African languages can hold their own with English in particular (for example, as Wildsmith-Cromarty and Gordon (2009) point out, the complexities regarding the development and use of the (11 official) home languages for communicating scientific and mathematical knowledge are significant), and the expansion of home-language instruction and bilingual programmes in the higher education sector has effected a meaningful and beneficial impact on student performance (e.g. Cain, 2013), any such academic literacy intervention must operate in the *lingua franca*.

For the most vulnerable of students at one South African university seeking formal access to mainstream science study, facilitating epistemic access to the foundation module which has emerged as a particular risk to their academic progression, by integrating fundamental scientific literacy development into the Foundation Biology curriculum is undeniably worth trialling. This offers an opportunity to act on the countries' education policies of equity and transformation: to ensure that a student granted access to study also has a fair opportunity to succeed (DoE, 1997b), and 'that the existing languages of instruction do not serve as a barrier to access and success' (DoHET, 2002, p. 5).

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Notes

1. In line Statistics South Africa (2014), the term 'Black African' used in this paper describes the 'population group' that excludes Coloureds and Indians.
2. South African secondary schools are categorised into quintiles according to the national Department of Education's 'Poverty Index' which is used for resource targeting purposes. National Quintile 1 (NQ1) includes the poorest (most disadvantaged) and NQ5, the least poor schools (DoE, 2006). Information pertaining to the quintile of the schools attended by the foundation students was accessed from this national department's management system (DBE, 2012).

3. The post-democracy curriculum, the National Curriculum Statement (NCS), was introduced in a phased manner, and by the end of 2008, all South African learners in Grade 12 wrote the same national exams for the first time. This common NSC exam replaced the SC. The NCS is recognised to differ in many respects from the former school curriculum in terms of organising principles, curricular content and emphasis on skills, sequence, progression and pacing of the curriculum, and teaching approaches and methodologies (Grussendorff et al., 2010). In addition, the subjects which make up the NCS are offered at one level only, dispensing with Higher Grade (HG) and Standard Grade (SG, less cognitively challenging) levels formerly used.

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