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Profiling our Students' Learning Orchestrations to Evaluate the Biology Curriculum

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Abstract

We have identified the major shifts in individual student study orchestrations over the first semester of a university biology course. We offer evidence that our curriculum, designed and taught by generalist biologists, has engaged generalist degree students. Professional degree students have not engaged with this course to the same level and many were demonstrably dissonant. At the end of semester, dissonant students, from both generalist and professional degrees, demonstrated little engagement with the curriculum, which is consistent with previous reports of the high degree of disengagement of first year students. The challenge to improve the engagement of students in professional degrees and to address the tendency towards dissonance and disengagement by our first year students is discussed and improvements in engagement are likely to be aided by systems that allow students to assess for themselves their approaches to study and conceptions of discipline development over the course of their degree.

Introduction

Changes in the higher education system include operating in a post-industrial environment characterised by turbulent change, information overload, competitiveness, uncertainty and, sometimes, organisational decline (Becher & Trowler, 2001). Competition between institutions has led to the development of curricula that are more professionally-oriented to attract increasing numbers of students and an explosion of discipline areas not previously included in university courses (e.g. sports science, environmental sciences) (Clark, 1997). A recent analysis from the UK reports that applications to enrol in professional degree courses have increased by an average of 26% since 2007 compared to an increase of only 6% for applications to enrol in non-professional degree courses (Hong Kong & Shanghai Banking Corporation, 3rd August, 2013).

In Australia, the Bradley review (Bradley, Noonan, Nugent, & Scales, 2008) correctly predicted that Australian universities would be required to support the student learning needs of cohorts of students comprising an even greater level of heterogeneity than currently exists. The change from elite to mass higher education (HE) has occurred in all industrialised countries and has resulted in the sector having an increasingly heterogeneous population of students with respect to incoming academic performance, socioeconomic status, and expectations of what it means to be a graduate. This study is situated in a large research-intensive Australian university, in a sector that has become increasingly performative (Ball, 2010). We do not advocate more data collection for the sake of compliance alone; we are interested in examining our biology teaching by exploring how our increasingly diverse student body engages with our biology curriculum. Does our biology curriculum provide an intellectually-stimulating environment for a diverse student body, and so suit both generalist degree and professional degree students?

We are mindful that students' experience in their first year, involving a transition to an environment where they are expected to be independent adult learners, can be daunting. About a third of students consider leaving in their first year and student success is largely determined by student experiences in their first year classes (Kift, 2014; Kift & Field, 2009). The literature on the first year experience and exploring notions of disciplinarity in the context of teaching and learning has informed our thinking as to how to construct and deliver a curriculum suitable for our first year students. According to the discipline categories of Biglan (1973a), as biology scholars, our discipline aligns with a 'hard, pure' category as do the disciplines of physics and chemistry. Our teaching objective is to offer a curriculum that is both sufficiently *deep* and engaging for those continuing in biology and sufficiently broad and relevant for all other students, including those classified by Biglan as 'applied' (e.g. Pharmacy, Nursing, Nutrition and Agriculture students).

A study by Krause, Hartley, James and McInnis (2005) divided the degrees that students were undertaking at first year level into 'interest-related' and 'job-related', with job-related students being interested in the profession and presumably the relevance of their subjects to their professional aspirations and not necessarily in the 'enabling' subjects that are course requirements or pre-requisite learning. James, Krause and Jennings (2010) report that, from 1999 - 2009, there was a marked increase in students knowing what occupation they want and being clear about what motivated them to enrol at university. Figure 1 illustrates the discipline breadth of first year biology students (as determined by degree enrolled) when mapped onto Biglan's discipline matrix (1973a). Of these students, 56% are enrolled in the Faculty of Science; 32% are enrolled in specialist degrees such as Environmental Science, Psychology and Nutrition, and only 23% are enrolled in the generalist Bachelor of Science (BSc) degree, with a small percentage enrolled in double degrees. Just under half of our cohort is enrolled in faculties other than Science. Given the level of 'service teaching' in our first year biology classes, we would hope that we offer a sufficiently robust curriculum to satisfy the learning agendas of all our students.

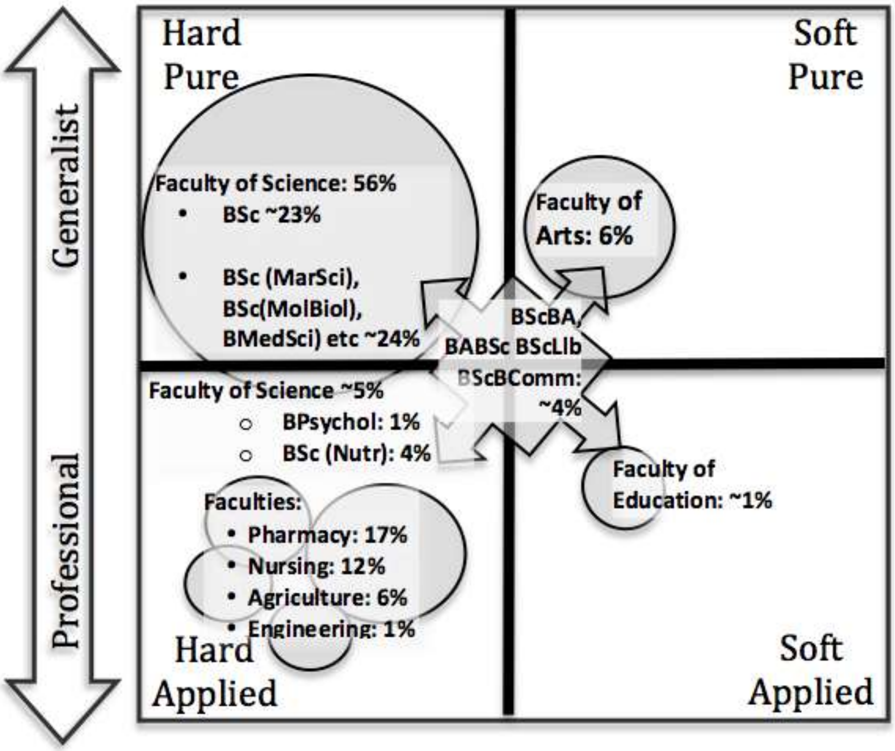

Figure 1: The diversity of our first year students and how their degree programs map onto Biglan's 'hard - soft', 'pure - applied' discipline matrix. Our discipline designations differ a little from Biglan's as our institutional context is different.

Biglan (1973a, 1973b) investigated practitioners' perspectives on their academic disciplines and by using multidimensional scaling of subject matter characteristics he showed that three dimensions appear to characterise the subject matter of academic areas in most institutions. These dimensions involved (a) the existence of a single paradigm (hard/soft), (b) concern with practical application (pure/applied), and (c) concern with life systems (Biglan 1973b). Biglan's classification system is supported by the later work of Hargens (1996), who used a different methodology, that of de Solla Price (1965), to investigate the characteristics of a discipline. Biglan's three dimensions provide a useful framework for studying the cognitive style of students in different areas, particularly at the point of entry into the discipline as they commence first year university. Are there aspects of the curriculum that we could improve to enhance the student learning experience of these 'applied' students who are enrolled in professional degrees? Some of our previous work on scientific numeracy made clear that students need to see the relevance of discipline content if they are to assimilate it appropriately, and this can prove especially difficult for students in professional degrees. The characteristics of a discipline are likely to have implications for how curricula are designed as well as how the learning environment is perceived by the students, particularly when the students represent a range of disciplines. There is the notion that students can adopt different orchestrations for different disciplines and here, where we can control for discipline by looking at learning in biology, we are in a unique position to assess the level to which degree perspective (generalist or professional) influences learning orchestration in a generalist course.

The combinations of variables such as 'study approach' with learning context have been described by Meyer (1991) as 'study orchestrations'. Students with dissonant orchestrations have incoherent or atypical linkages between variables; students with consonant orchestrations have variables that present coherently, e.g. *surface* approach to learning has a high score with *deep* approach to learning being low (e.g. Anderson, Lee, Simpson, & Stein, 2011; Cano, 2005). Crawford, Gordon, Nicholas and Prosser (1998) have used cluster analysis to identify students with similar orchestrations, consonant or dissonant, with respect to conceptions of mathematics and how these relate to their approaches to learning mathematics, their experiences of studying the subject and their performance on assessments. We note the criticism of the Biggs' 'surface'- 'deep' model (Howie & Bagnall, 2013) but we also note that this model has assisted us to reflect on our own practices and curriculum design.

This is our fifth paper in a series wherein we have analysed the learner characteristics of a large group of students moving from school to university, and the way these characteristics change through their first semester of biology at university (Quinnell, May, Peat, & Taylor, 2005; May, Peat, Taylor, & Quinnell, 2006; Taylor, Peat, May, & Quinnell, 2007). We have demonstrated that those students whose *orchestration* (i.e. *approaches to study, conception of biology, course experience*) reflected 'disengagement' at the start of semester were unlikely to change their learning orchestration by the end of semester (Quinnell, May, & Peat, 2012).

Given the current trend in the higher education sector to broaden participation and for both educators and students to focus on vocational training, our aim now is to determine the levels of curriculum engagement at the start and at the end of the semester of students in generalist degrees compared to students in professional degrees in order to assess the extent to which our curriculum 'delivers' at a first year level where engagement is critical, not the least because of attrition. Are we catering for our students' expectations as they enter university? Is our curriculum sufficiently inclusive for such a diverse cohort studying a range of disciplines including both generalist and professional?

Method

The 2005 biology students were surveyed in class at the start and at the end of first semester in their first year of an introductory biology course. The course is delivered as a typical 'lecture-laboratory' undergraduate course over a semester, and serves as a core subject for further study in biology as well as a compulsory foundation course for other degree programmes. The survey incorporated:

- The Study Process Questionnaire (SPQ) (Biggs, 1987) where the two subscales, *surface approach* and *deep approach*, each contained 14 items; offered at both the start and end of semester.
- The Conceptions of Biology Questionnaire (CBQ) (validated and used in our earlier work, which was modified from Crawford et al. 1998) where the two subscales, *fragmented conception* and *cohesive conception*, each contained 10 items (Quinnell, et al., 2005), offered at both the start and end of semester.
- Unit Evaluation Questionnaire (UEQ) (Ramsden, 1991). The UEQ comprised five subscales that measured students' perceptions of the quality of teaching (*good teaching;* 6 items), whether goals were set and communicated for the unit of study (*clear goals;* 5 items), whether the workload was suitable (*appropriate workload;* 5 items), whether assessment tasks encourage *deep* learning practices (*appropriate assessment;* 6 items), and whether the unit included a suitable level of independent study (*independence;* 6 items), offered only at the end of semester.

Students scored survey items according to a five-point Likert scale. Because the Likert scales comprised a number of items (as indicated above and also in Table 1) the use of mean scores is legitimised in our statistical analyses. Student's t-tests were used to compare mean 5-point Likert scores between Survey 1 (at the start of semester) and Survey 2 (at the end of semester) for each subscale parameter. A Likert mean < 3.0 indicates disagreement with the subscale, equal to 3.0 indicates neutrality and > 3.0 indicates agreement with the subscale. Clusters are based on z scores for the whole cohort (n = 597). z scores measure the degree of deviation from the cohort mean when the mean is set to zero. The level of deviation from the z score mean (0) is considered significant if $z > | 0.3 |$; hence z scores $< | 0.3 |$ have been presented in grey text in the results tables.

To ensure student anonymity, in accordance with ethical practice, students were not identified by name or student number. A coding system was used to match the survey data of individual students to information about the degree in which they were enrolled and to measures of academic performance. We had a large group of students (n=597) for whom we had a complete data set, which in addition to the survey responses included: university entry score (this reflects 'general intelligence', general aptitude at secondary school level and is aggregated across several subjects at the point before students enter university) (University Admission Index, UAI, now replaced with the Australian Tertiary Entrance Rank); degree enrolled; and all assessment marks, final mark and grade in tertiary biology. Fifty-six percent of these 597 students were enrolled in generalist degree programs (in Science, Arts, Social Sciences, Commerce) and the rest were enrolled in professional degrees (Pharmacy, Nursing, Nutrition, Agriculture).

We employed hierarchical cluster analysis to identify the *learner profiles* at the start of the semester; these initial clusters were established using the standardised mean scores (z scores) for each subscale variable from the Survey 1 data and hierarchical cluster analysis (Ward's method) (Trigwell, Hazel, & Prosser, 1996; Trigwell, Prosser, & Waterhouse, 1999; Prosser, Trigwell, Hazel, & Waterhouse, 2000; Quinnell et al., 2012). Four clusters were resolved from the students' responses to the survey at the start of the semester.

By adding the responses to the UEQ at the end of semester we were able to look for association(s) between *learner profiles* and students' perceptions of our curriculum. The four initial clusters each resolved into two daughter-clusters when the student survey responses from the end of semester survey were analysed using sequential hierarchical cluster analysis (Quinnell et al., 2012). Only those daughter clusters that are supported by the increasing value of the Squared Euclidean Distance are included here and between-group (-cluster) contrasts were determined using ANOVA.

Post-hoc Chi-squared analyses used the ratio 56%: 44% to generate expected values within each Learner Profile cluster (as resolved using hierarchical cluster analysis) of generalist: professional degree students and so determine whether the generalist or professional degree students were over/under-represented in each daughter cluster, which are based on the end of semester z scores (of the whole study group, n=597) for *surface*, *deep*, *fragmented* and *cohesive* and are derived from one of the initial clusters. We have described this process of sequential hierarchical cluster analysis in our earlier work (Quinnell et al., 2012). All analyses were performed using SPSS software.

Results

The study group

Our study group, n = 597, is representative of the cohort at large (those who completed at least one survey) with respect to the scale scores for each variable (approach to study: *surface*, *deep*;

conception of biology: *fragmented*, *cohesive*; unit of study evaluation: *good teaching*, *workload appropriate*, *clear goals*, *independence*, *assessment*). The mean scores of the study group are not significantly different to the scale scores from all available survey data (Supplementary material: Appendix). Using t-tests to compare the mean subscale scores from the start to the end of the semester, we found that there have been some overall changes in the responses to the SPQ and CBQ surveys (Table 1).

It is not surprising that students entering their first semester of biology exhibit a desirable learning orchestration - positive for both *deep approach to study* and *cohesive conception of biology* - since the university where this work was conducted has a relatively high university entry requirement. What is surprising is that the *surface* and *fragmented* survey responses increased and *deep* and *cohesive* responses decreased (towards neutral) (Table 1) over the course of one semester of tertiary study. The UEQ aggregated data indicate that the cohort at large was 1) overall neutral for some aspects of our curriculum (*clear goals* and *good teaching*), 2) overall positive about the assessment being appropriate and encouraging *deep* approaches to study, and 3) overall negative about the levels of independence required and the workload being appropriate. If the analysis was limited to just these data, the inference would be that our curriculum encourages *surface* approaches to study, discourages students to take *deep* approaches to study (at odds with the increase in UEQ *assessment* subscale data), and conceptions of biology are more *fragmented* and less *cohesive*. But the observed shifts are not because every student has become, for example, a little less *deep* and a little less *cohesive* (Table 1); rather, these data can be explained as the total shift for the cohort towards *deep approaches to study* is less than the total shift away from *deep approaches to study*. To examine changes in approach to learning and conception further we used cluster analyses to identify groups of students who share particular learner characteristics.

Initial profiling: Assessing the learner characteristics of students at the start of semester

Using the approaches to study questionnaire (*surface* and *deep*) and conceptions of biology questionnaire (*fragmented* and *cohesive*) survey response data from the students for whom we had complete data sets we were able to resolve four clusters of students. Students within each cluster share a particular 'learning orchestration' that is different from that of students in the other three clusters. The statistically significant characteristics of these clusters are described in Table 2 and arrows indicate where each cluster differs from the overall means, which, as we have noted above, are not 'neutral'. Analysis of variance of the UAI entry scores tells us that there is no significant difference across the four clusters with regards to this particular measure of academic performance. We used *post hoc* Chi-squared analysis to test our assumptions of the compositions of the learner profiles of clusters with respect to distribution of generalist and professional degree students across these clusters.

We have described the students in Cluster 1 (n = 190; 32%) as *tending to deep* as they have responded even more positively to the *deep* items on the survey (generating a mean subscale score of 3.6) than the cohort average (3.5); a z score of +0.3 indicates that this difference is statistically significant. Significantly, these students do not take a *surface* approach to their learning, nor do they have *fragmented* conceptions of biology (mean scores for both *surface* and *fragmented* are lower than for the cohort mean (< 3) and z scores are < -0.3). The students in this cluster have *cohesive* conceptions of biology (mean subscale score 3.8) and this is consistent with (and not significantly different from) the cohort as a whole, where conceptions of biology are high. With respect to students profiling as *tending to deep* and *away from surface and fragmented* at the start of semester, this cluster (Cluster 1) is enriched with students enrolled in generalist degrees (66%, Table 2).

Table 1: Comparison of mean subscale scores of students who completed Survey 1 and Survey 2 for approach to study and conception of biology; n = 597

	Subscale[1]	**mean Likert**[2] **subscale score**		**means compared using t-test**
		Semester start	**Semester end**	
Approach to studying	*surface*** (14 items)	3.2	3.4 ↑	significant increase in mean score for this subscale variable shifting to an increase in surface approach to learning ($p = < 0.01$)
	*deep*** (14 items)	3.5	3.2 ↓	significant decrease in mean score for this subscale variable, tending to neutral ($p = < 0.01$)
Conception of biology	*fragmented*** (10 items)	2.9	3.0 ↑	significant increase in mean score for this subscale variable, tending to neutral ($p = < 0.01$)
	*cohesive*** (10 items)	3.9	3.8 ↓	significant decrease in mean score for this subscale variable, tending to neutral ($p = < 0.01$)
Unit of study experience questionnaire	*clear goals* (5 items)		3.0	neutral
	independence (6 items)		2.6	“disagree” that the level of independence was appropriate
	good teaching (6 items)		3.0	neutral
	workload (5 items)		2.7	“disagree” that the level of workload was appropriate
	assessment (6 items)		3.2	“agree” that the level of assessment encouraged deep approaches to learning

[1] number of items in each subscale indicated in brackets

[2] 5-point Likert scale: a score of < 3.0 indicates disagreement/rejection, 3.0 is neutral, > 3.0 indicates agreement/support. Significant differences between subscale parameters indicated as: * = sign diff at $p = 0.05$; ** = sign diff at $p = 0.01$. Arrows indicate direction of change in mean score for that subscale: ↑ = increase in subscale score; ↓ = decrease in subscale score.

Table 2: Learner Profiles at the start of semester derived from cluster analysis of Survey 1 *SPQ* and *CBQ* scores and including performance metrics and distributions of students undertaking generalist and professional degrees

Variable	Subscale	*Mean for study group n = 597*	Learner profiles at the start of semester							
			Cluster 1 n = 190 32%		**Cluster 2 n = 59 10%**		**Cluster 3 n = 217 36%**		**Cluster 4 n = 131 22%**	
Learning characteristics			*Tending to* deep *& away from* surface-fragmented		*Strongly* deep & cohesive		*Tending to dissonance*		*Surface strategists*	
			mean	[2]*z* score	mean	*z* score	mean	*z* score	mean	*z* score
Approach to studying	[1]*Surface ***	*3.2*	**2.8↓**	**-0.8**	**3.2**	-0.1	**3.5↑**	**0.5**	**3.4↑**	**0.4**
	*Deep ***	*3.5*	**3.6↑**	**0.3**	**4.0↑**	**1.2**	**3.5**	0.1	**2.9↓**	**-1.2**
Conception of biology	*Fragmented ***	*2.9*	**2.6↓**	**-0.7**	**3.1**	**0.6**	**3.0↑**	**0.4**	**2.9**	0.2
	*Cohesive ***	*3.8*	**3.8**	-0.2	**4.6↑**	**1.8**	**3.9**	0.2	**3.5↓**	**-0.8**
Performance	[2]UAI^{ns}	*91.6*	92.1		92.6		90.8		91.8	
generalist: professional		*56%:44%*	66%:34%**		67%:33%^{ns}		53%:47%^{ns}		42%:58%**	

This analysis is derived from Survey 1 responses from students who submitted a complete Survey 2 (n = 597). Students within each cluster share an approach to learning and conception of biology. Significant differences between subscale parameters for clusters indicated as: ns = no significant difference; * = sign. diff. at p = 0.05; ** = sign. diff. at p = 0.01.

[1] All subscales *(surface, deep, fragmented, cohesive)* were 5-point Likert scales: a mean of < 3.0 indicates disagreement/rejection, 3.0 indicates neutral, > 3.0 indicates agreement/support. *z* scores are given for subscale variables as indicated. *z* score values > |0.30| indicate students in the cluster scored significantly above ($z > 0.3$) or below ($z < -0.3$) the mean for the cohort on the specified subscale. *z* score values < |0.30| greyed.

[2] Students' UAI scores are given here for completeness of the cluster profile. There was no significant difference (ns) in UAI between clusters.

We have described the students in Cluster 2 (n = 59; 10%) as *strongly deep and cohesive* as they have the highest mean subscale scores across all initial clusters for these characteristics (4.0 and 4.6, respectively). Both subscales for *surface* and *fragmented* are close to neutral, with the *surface* score consistent with the cohort average and not significantly different from those of the three other clusters and the *fragmented* mean score being significantly higher than those of the other cohorts. Given the high *deep* and *cohesive* scores, the significance of the elevated score for *fragmented* was a little difficult to interpret and could be a reflection of high school biology not being a prerequisite for studying biology at tertiary level. Here we have based our cluster description on the fact that the scores for *deep* and *cohesive* are high, and the scores for *surface* and *fragmented* are close to neutral. With respect to students profiling as *deep and cohesive* at the start of semester, the distribution of generalist and professional degree students is not significantly different to that of the overall cohort (Cluster 2, Table 2).

The students in Cluster 3 (n = 217; 36%) have a significantly higher mean scale score for *surface.* Although their responses to the *fragmented* conceptions of biology question items were overall neutral (mean subscale score of 3.0), this is higher than for the overall cohort so, comparatively, these students have more *fragmented* conceptions of biology than their peers. *Deep* and *cohesive* mean scale scores are consistent with the means for the overall cohort, which is > 3.0. Because all mean scale scores are 3.0 or greater and these students take both *surface* and *deep* approaches study and have *cohesive* and (relatively) *fragmented* conceptions of biology, we have described the students in Cluster 3 as *tending towards dissonance*. Dissonance here means that the students have learning characteristics that show an incongruent orchestration. With respect to students profiling as *dissonant* at the start of semester, the distribution of generalist and professional degree students is not significantly different to that in the overall cohort (Cluster 3, Table 2).

The students in Cluster 4 (n = 131; 22%) have a significantly higher than average mean scale score for *surface* approach to study and this is congruent with their lower than average mean score for *deep* approach to study. Relative to the overall cohort, this cluster has poorer conceptions of biology: the mean scale score for *fragmented* conception is <3.0 (2.9, the same as the overall cohort) and mean scale score for *cohesive* conception for this group, despite being 3.5, is significantly lower than for the other three clusters. Again, perhaps this lower *cohesive* score is an indication of students who did not complete high school biology. We have described these students as *surface achieving*: their approach to learning is *surface* and their score for conceptions of biology, although lower than the cohort average, is <3.0. These students have performed well enough in high school to gain entry into university. The cluster where students are *surface-achieving* is enriched with students enrolled in professional degrees (Cluster 4, Table 2).

End of semester profiling and assessing fluidity of learning orchestrations

Using sequential cluster analysis, where the matched student response data from the end of semester is used to assess the homogeneity of the initial clusters (Quinnell et al., 2012), we identified students who had changed their learning characteristics. Using *post hoc* Chi-squared analysis, we determined if there were any significant differences in the distribution of generalist and professional degree students in each cluster. Some students demonstrated that they had changed their approaches to study, and some students did not seem to have changed very much at all. Descriptions of each of these second-tier clusters (daughter-clusters) are described here in relation to their initial (or parent) cluster (when mean subscale scores are compared) and to the whole study group of 597 students (when the z scores are compared, a z score >|0.3| being significant). As with university entrance scores, academic performance at the end of semester showed no statistical difference between clusters.

Changes in the 'generalist' student cluster from the start of semester

At the end of semester, the students who started out tending to be *deep* could be split into two daughter-clusters that were statistically different (Table 3). These students started off discriminating between *fragmented* and *cohesive* conceptions of biology, indicating to us that they had an interest in biology, and were tending to adopt *deep* approaches to study. By the end of semester, just over half (daughter-cluster 1a, Table 2) had increased their mean subscales for *surface* (2.8 to 3.3, a shift from being negative for *surface* to being positive to *surface*) and *fragmented* (2.6 to 2.9, a shift to neutral). These students have retained their *cohesive* conception of biology (3.9 both at the start and at the end of semester); these students are now less discriminatory with respect to being able to identify items that indicate a *fragmented* conception of biology (2.6 to 2.9, which is close to neutral). Because the consensus shift for these students is towards neutral, we describe these students as both *dissonant* and *disinterested*. The students in daughter-cluster 1b demonstrate the ideal biology learning orchestration (>3 for both *deep* and *cohesive*; <3 for *surface* and *fragmented*) and for these parameters are statistically different from their sister-cluster (based on ANOVA) and the cohort means with z scores > |0.3|; this group of students has had more positive engagement with elements of the curriculum than the students in the sister-cluster (significantly higher subscale scores for *good teaching* [3.2 compared to 2.9 in cluster 1a] and *workload* [3.2 compared to 2.7 in cluster 1a]). Daughter-cluster 1b is enriched with generalist degree students and their responses to the curriculum have been more positive when compared to the cohort as a whole with respect to *workload* (*z* score of 0.7) and *assessment* (*z* score 0.5).

Changes in the 'deep' and 'cohesive' cluster from the start of semester

Cluster 2 was the smallest with only 59 students. At the start of semester we described this cluster as being strongly *deep* and *cohesive*. By the end of semester (Table 4), about half (daughter-cluster 2a) had remained strongly *deep* and *cohesive* with mean subscale scores for *deep* and *cohesive* dropping slightly (4.0 to 3.9 and 4.6 to 4.3, respectively). These students have retained their *cohesive* conception of biology (mean subscale score of 3.9 both at the start and at the end of semester) and are now less discriminatory with respect to being able to identify items that indicate a *fragmented conception of biology* (2.6 to 2.9, which is close to neutral or 3). On the other hand, daughter-cluster 2b has become dissonant, with mean subscale scores >3.0 for all *approaches to study* and *conceptions of biolog*y subscale scores. Students in both daughter-clusters 2a and 2b were positive about the level of independence required in the unit of study, but the students who stayed strongly *deep* and *cohesive* (2a) were also positive about the standard of teaching and that the assessments encourage *deep* approaches to study. Because the consensus shift for these students is towards neutral, we describe these students in daughter-cluster 2a as *disinterested* because they had poor or neutral engagement with elements of the curriculum. The distribution of generalist and professional degree students in the daughter-clusters (2a and 2b, Table 4) is not significantly different to that of the cohort as a whole.

Changes in the 'dissonant' cluster from the start of semester

We described Cluster 3 at the start of semester as having a tendency to *dissonance* as they had more *fragmented* conceptions of biology than their peers as well as being in agreement with items on the *deep* and *cohesive* subscales. At the end of the semester about a quarter of these students still did not have a sound conception of biology (both *fragmented* and *cohesive* > 3.0, and respectively higher and lower than the cohort as a whole) (Table 5). These students are only taking a *surface* approach to learning*;* recall that at the highly aggregated level, *surface* approach to learning increased from the start to the end of semester (Table 1). The students in daughter-cluster 3a had overall negative engagement with the curriculum (significantly lower *good teaching* subscale score than the whole cohort and when compared to students in their sister-cluster (3b) who were >3.0 for *good teaching*. We have described these students as *disinterested*. At the end of semester, students in daughter-cluster 3b (the bulk of the students derived from Cluster 3) are predominantly taking a *surface* approach to study and have not demonstrated a consonant conception of biology. The mean final mark for students in daughter-cluster 3b is significantly higher ($p = 0.05$) than that of their sister- cluster (Cluster 3a); students in daughter-cluster 3b have not engaged well with biology but are good *surface achievers*.

Changes in the 'surface achievers' cluster from the start of semester

We described Cluster 4 at the start of semester as being *surface achieving* as they have lower *z*-scores for *deep* approaches and *cohesive* conceptions than their peers (-1.2 and -0.8, respectively), and a higher *surface* approach to learning *(z* score of 0.4). Like all of the students who are offered a place at our university, these students performed well in high school and, from their *fragmented* conception of biology responses, they can demonstrate some level of discrimination between *fragmented* and *cohesive* items (mean subscale score for *fragmented* conception = 2.9, which is close to neutral; mean subscale score of 3.5 for *cohesive* conception of biology, Table 6). This cluster was enriched with professional degree students. At the end of the semester, the bulk of the students had identical mean subscale scores for approaches to learning and conception of biology but were comparatively less *deep* and less *cohesive* and more *fragmented* than the cohort as a whole (Table 6). Points of difference stand out from these data: the academic performance of daughter-cluster 4a was poor compared to their sister-cluster

(cluster 4b) ($p = 0.05$) and when compared to the cohort at large (*z* score -0.4); daughter-cluster 4b were more negative about the *teaching*, *workload* and *assessment* than any daughter cluster. Like their parent cluster, the two daughter-clusters have a higher proportion of students in professional degrees (daughter-clusters 4a, b, Table 6).

Table 3: Daughter Profiles following sequential cluster analysis of the students who were initially *"tending to deep"* orchestrations

				Daughter clusters at the end of semester			
Variable		**Cluster 1** n = 190 (32%)		**Cluster 1a** n = 109 (18%)		**[2]Cluster 1b** n = 81(14%)	
		mean	[1]z score	mean	*z* score	mean	*z* score
Approach to studying	*surface***	**2.8**	**-0.8**	**3.3↑**	-0.2	**2.9↑**	**-1.0**
	*deep***	**3.6**	**0.3**	**3.2↓**	-0.1	**3.7↑**	**0.9**
Conception of biology	*fragmented***	**2.6**	**-0.7**	**2.9↑**	-0.2	**2.6**	**-0.8**
	*cohesive***	**3.8**	-0.2	**3.8**	-0.1	**4.0↑**	**0.4**
Unit of study experience	*clear goals*^{ns}	-		**2.9**	-0.1	**3.0**	0.0
	independence^{ns}	-		**2.5**	-0.1	**2.6**	0.0
	*good teaching***	-		**2.9**	-0.2	**3.2↑**	0.2
	*workload***	-		**2.7**	-0.1	**3.2↑**	**0.7**
	assessment^{ns}	-		**3.2**	0.1	**3.5↑**	**0.5**
Performance	UAI (mean)	92.1	0.1	-		-	
	Final mark^{ns} (mean)	-		66.2	0.2	65.8	0.2
generalist: professional degree students	56%:44% n = 597	66%:34%**		60%:40%^{ns}		75%:25%**	

1. values < |0.30| greyed; *z* scores relate to the total cohort ($n = 597$).
2. Cluster has attributes similar to the parent cluster in terms of approach to learning and conception of biology. Percentages relate to the size of the total cohort ($n = 597$).
3. Significant difference between subscale parameters for Daughter Profiles: ns = no significant difference; * = sign diff at $p = 0.05$; ** = sign diff at $p = 0.01$. "-" = parameter not applicable.

Students' perceptions of the learning environment

The UEQ data tell us that most of our students have mixed perceptions of the curriculum (Table 1). On the one hand, the overall means of *assessment* were positive and on the other hand, the levels of *independence* and *workload* were perceived poorly. *Good teaching* and *clear goals* were overall neutral. The three largest end of semester daughter-clusters are neutral across the board for the UEQ: 1a, n = 109 (Table 3), 3b, n = 161 (Table 5) and 4a, n = 105 (Table 6). Looking at these data we have to acknowledge our naivety in thinking that we knew why our students were undertaking a course in biology. Although the majority of our students may well have started off wanting to do biology, the overall lack of positive perceptions about the curriculum for two-thirds of the students tells us that we have not met their expectations. Students who were *consonant* at the end of semester (daughter-clusters 1b, Table 3 and 2a, Table 4) perceived that our *assessments* were encouraging *deep* learning and the *workload* to be appropriate. Students who had negative perceptions of the learning environment (specifically those students whose negative perceptions of *assessments* encouraged deep learning and *workload* being appropriate) had adopted strongly *surface approaches to study* (daughter-clusters 3a in Table 5 with n = 59; 4b in Table 6 with n = 26). It is our view that negative responses to the curriculum indicate critical engagement and are preferred to students adopting an overall neutral stance.

Table 4: Daughter Profiles following sequential cluster analysis of the students who were initially *deep* and *cohesive* learners

Variable		**Cluster 2** n = 59 (10%)		**Daughter clusters at end of semester** [2]**Cluster 2a** n = 30 (5%)		**Cluster 2b** n = 29 (5%)	
		mean	[1]z score	mean	*z* score	mean	*z* score
Approach to studying	*surface***	**3.2**	-0.1	**3.1↓**	**-0.5**	**3.7↑**	**0.7**
	*deep***	**4.0**	**1.2**	**3.9↓**	**1.3**	**3.4↓**	**0.4**
Conception of biology	*fragmented***	**3.1**	**0.6**	**2.8↓**	**-0.4**	**3.3↑**	**0.8**
	*cohesive***	**4.6**	**1.8**	**4.3↓**	**1.3**	**3.8↓**	0.1
Unit of study experience	*clear goals^{ns}*	**-**		**3.1**	**0.4↑**	**3.1**	**0.3↑**
	independence^{ns}	**-**		**2.8**	**0.4**	**2.6**	0.2
	*good teaching***	**-**		**3.3↑**	**0.3**	**3.0**	-0.1
	*workload***	**-**		**2.9↑**	**0.3**	**2.8**	0.2
	assessment^{ns}	**-**		**3.2**	0.0	**3.1**	-0.2
Performance	UAI (mean)	92.6	0.1	-		-	
	Final mark^{ns} (mean)	-		66.6	0.2	64.4	0.0
generalist: professional degree students	56%:44% n - 597	66%:34%**		60%:40%^{ns}		75%:25%**	

1. 2. 3. See Table 3 for explanations.

Table 5: Daughter Profiles following sequential cluster analysis of the initially *surface* learners

Variable		**Cluster 3** n = 217 (36%)		**Daughter clusters at end of semester** [2]**Cluster 3a** n = 56 (9%)		**Cluster 3b** n = 161 (27%)	
		mean	[1]z score	mean	*z* score	mean	*z* score
Approach to studying	*surface***	**3.5**	**0.5**	**3.4↓**	0.1	**3.6↑**	**0.5**
	*deep***	**3.5**	0.1	**2.9↓**	**-0.6**	**3.3↓**	0.2
Conception of biology	*fragmented***	**3.0**	**0.4**	**3.2↑**	**0.4**	**3.1↑**	0.3
	*cohesive***	**3.9**	0.2	**3.3↓**	**-1.2**	**4.0↑**	**0.4**
Unit of study experience	clear goals^{ns}	**-**		**2.9**	-0.1	**3.0**	0.1
	independence^{ns}	**-**		**2.5**	-0.1	**2.6**	0.1
	good teaching**	**-**		**2.9**	**-0.3**	**3.2**	0.2
	workload^{ns}	**-**		**2.6**	-0.1	**2.6**	-0.1
	assessment^{ns}	**-**		**3.1**	-0.1	**3.1**	-0.1
Performance	UAI (mean)	90.8	-0.1	-	-		
	Final mark (mean)*	-		59.8	-0.4	63.7	0.0
generalist: professional degree students	56%:44% n=597	53%:47%^{ns}		57%:43%^{ns}		51%:49%^{ns}	

1. 2. 3. See Table 4 for explanations.

Table 6: Daughter Profiles following sequential cluster analysis of students who were initially '*surface achievers'*

Variable		**Cluster 4** n = 131 (22%)		**Daughter clusters at the end of semester**			
				[2]**Cluster 4a** n = 105 (18%)		**Cluster 4b** n = 26 (4%)	
		mean	[1]*z* score	mean	*z* score	mean	*z* score
Approach to studying	*surface***	**3.4**	**0.4**	**3.4**	-0.1	**3.9↑**	**1.1**
	*deep**	**2.9**	**-1.2**	**2.9**	**-0.7**	**2.6↓**	**-1.2**
Conception of biology	*fragmented***	**2.9**	0.2	**2.9**	-0.2	**3.6↑**	**1.4**
	*cohesive***	**3.5**	**-0.8**	**3.5**	**-0.7**	**3.8↑**	0.1
Experience	*clear goals*^{ns}	-		**2.9**	-0.2	**2.9**	-0.2
	independence^{ns}	-		**2.5**	-0.1	**2.5**	-0.1
	good teaching^{ns}	-		**3.0**	0.0	**2.8**	**-0.4**
	*workload***	-		**2.6**	-0.2	**2.2**	**-0.7**
	*assessment***	-		**3.2**	0.0	**2.7**	**-1.0**
Performance	UAI	91.8					
	Final mark*	-		61.3	-0.2	66.1	0.2
generalist: professional degree students	56%:44% n =597	42%:58%**		44%:56%**		35%:65%*	

1. 2. 3. See Table 4 for explanations.

Discussion

We have demonstrated that student orchestrations can change over the course of a semester. Major shifts in individual student study orchestrations can be determined using Learner Profiling and the data we have presented here provide further evidence that student study orchestrations are not fixed (Figure 2, see below). We have evidence that our curriculum is meeting the expectations of some but not all of our students as the curriculum:

(1) engages generalist degree students whose conception of biology is sound and whose study approach is intrinsic (daughter-cluster 1 b);

(2) engages students with positive learning orchestrations irrespective of degree program (daughter-clusters 2a and 2b);

(3) is less than ideal at meeting the needs of students in professional degrees who do not have *deep* approaches to study (daughter-clusters 4a and 4b); and

(4) has failed to engage students who demonstrated *dissonance* at the start of semester (Cluster 3) or who shifted to a *dissonance* by the end of semester (daughter-cluster 1a). The number of students shifting into *neutral* is, we believe, a reflection of the high degree of disengagement of first year students that has been reported in the literature (e.g. McInnes, 2001).

Does our curriculum encourage students to maintain (or adopt) deep approaches to study and develop cohesive conceptions of biology?

That students are shifting into neutral is, we believe, a reflection of the high degree of disengagement and attrition of first year students that has been reported in the literature (e.g. Shah and Nair 2010). A lack of interest in biology predominates in our first year cohort (~ 460 students, ~80%). Our data are from students who completed the introductory biology course and we are probably underestimating the level of disengagement: Shah and Nair (2010) report that almost 30% of the students who disengaged with university altogether cited as one of the main reasons that university was not what they expected and 17% of first year students left because they found the methods of teaching to be unmotivating (Brinkworth, McCann, Matthews, & Nordström, 2008). Furthermore, the Australian Government's Office of Learning and Teaching Student and Staff Expectations and Experiences Project (Office of Learning and Teaching 2014), have shown that there are large mismatches between science students' expectations and their experiences of first year university, especially in terms of workload, feedback and assistance they will receive. Our aggregated course experience questionnaire data align with this: i.e. students disagree that the workload or level of independence are appropriate. Our clustered data tell us that generalist students have engaged positively with our curriculum while our professional-degree students are critical of or disengaged with our curriculum (Figure 2).

Ramsden (2003) highlights that some students begin university with similar approaches to those they took in high school, where *surface* approaches are successful. Most of our students are school leavers (average age 18 years old) and are, according to our data (Table 1), arriving from high school with a net *surface* approach to study and this result is consistent with previous studies: school leavers score significantly higher for *surface* approaches in comparison to mature-aged students (e.g. Burton, Taylor, Dowling, & Lawrence, 2009; Zeegers, 2001), and this has been attributed to mature students being better able to plan and organise their time in response to the assessment schedule (Burton et al., 2009). Although our students have demonstrated a net increase in *surface* approach to study over the course of the semester, two of our eight daughter-clusters are taking a less *surface* approach to study at the end of the semester than they were at the beginning of the semester (daughter-clusters 2a and 3a). *Surface* approaches are the default when the workload is high and where the intention is to cope with course requirements (Entwistle & Peterson, 2004) and our data show that the net level of *surface* approach to study has increased over the semester and student perceptions of the workload was a discriminating factor in separating daughter-clusters.

Is our curriculum sufficiently inclusive for such a diverse cohort studying a range of disciplines including both generalist and professional?

Previous work has found that students enrolled as science majors are measurably more motivated than non-science majors (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011), lending a level of support for our assertion that generalist students in daughter-cluster 1b are motivated by interest to adopt *deep* approaches and engage positively with the curriculum. Intention and interest in the learning task can influence students' approaches to learning and studying (Entwistle & Peterson, 2004). This can be summarised as learning orientations, which are based on four social functions (academic, professional, social and personal) in combination with extrinsic or intrinsic interests (Entwistle & Peterson, 2004).

Biglan (1973b) describes the research of those operating in the applied disciplines as emphasising practical value and relevance and we know that 'relevance' is important to engage medical students with learning statistics (Thompson, 2008). Here, we present evidence that some, although not all, of those enrolled in professional degrees are not engaging as we would hope in a generalist-designed biology course. It remains an ongoing challenge to improve the curriculum and how it is delivered to make it more engaging and relevant to all our students. One major limitation is that enrolments into an already large first year cohort continue to increase while resources (including teaching venues) are at best holding steady.

Should we develop a teaching pedagogy that aligns to the profession and to the degree in which students are enrolled? Or should we offer students a blended pedagogy to address learning across the cohort including differences associated with degree (i.e. generalist degrees and professional degrees)?

We recognise that this division into generalist and professional degrees is somewhat over-simplified but it does explain some of the cohort's diversity with respect to motivation.

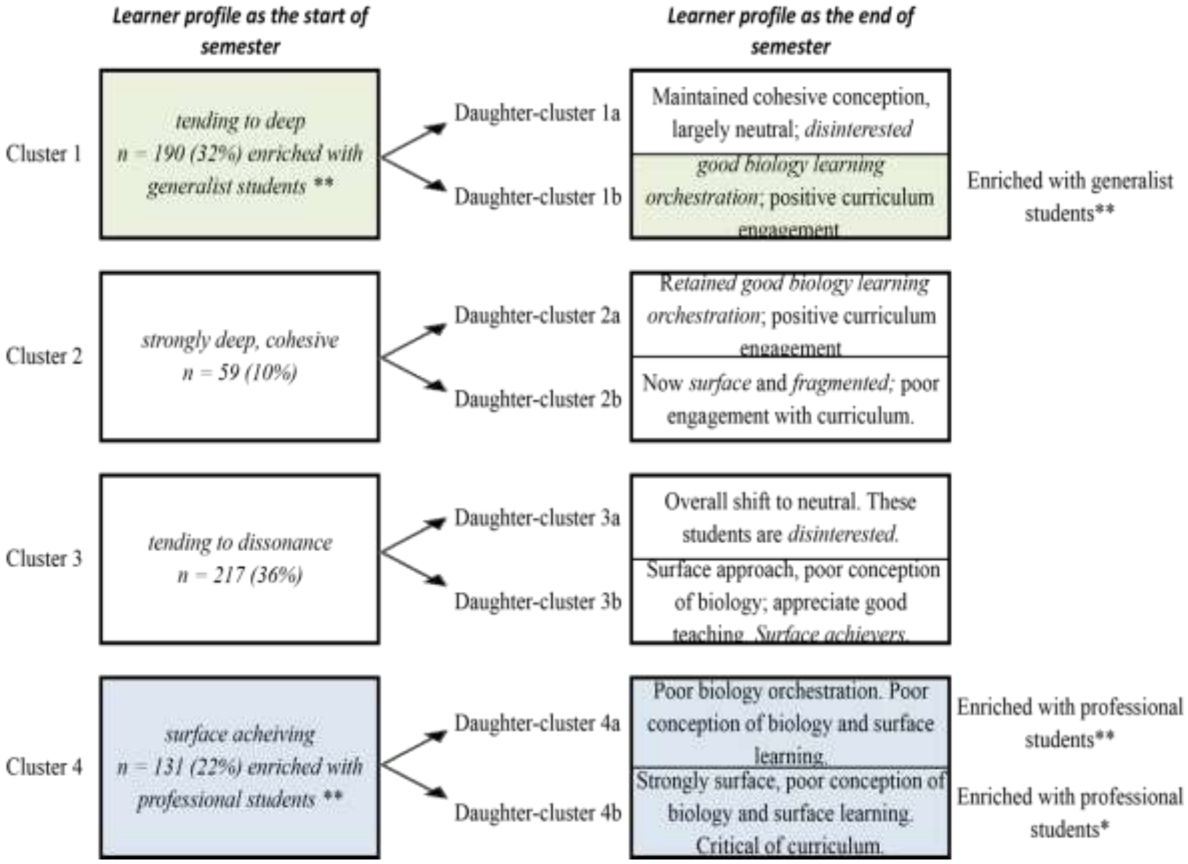

Figure 2: First year biology student learning profiling showing learning orchestration dynamics of generalist and professional degree students. **p<0.01; *p<0.05.

What is the way forward? Final thoughts

Although our first year students were high achievers at high school when they entered our subject, we acknowledge that they are all in transition into the university learning environment and may benefit from an intentional curriculum that focuses to engage commencing students in their learning (Kift, 2015). Jeffery (2007) advocates that students would benefit from more transparency from their instructors with respect to how to navigate the curriculum. This idea of transparency resonates with notions of revealing to students the hidden curriculum (Bergenhengouwe, 1987) and with engaging students with metalearning (Biggs, 1985) as advocated by Abbott, McFarlane and Pluske (2007) and Winters (2013).

Our work highlights that learning orchestrations are subject to change and possible approaches could include the development of technology-enhanced systems to:

(1) allow students to track the development of their own learning orchestrations (e.g. *approaches to study* and *conceptions of discipline*) over the course of their degree, and

(2) allow the meaningful evaluation of resources designed to support students navigating the curriculum, particularly those in transition from high school to higher education.

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Appendix

Comparison of the data from the study subjects with data from the whole cohort. Statistical analysis indicates that the data from the study subjects are representative across all variables of the cohort at large.

		mean Likert scores			
		all student data (n = up to 1500)	**study subjects** (n = 597)	**t-test p values (2 tailed and unequal variance)**	
Start of semester survey data					
Approaches to study	*surface*	3.2	3.2	0.35	ns
	deep	3.5	3.5	0.86	ns
Conceptions of Biology	*fragmented*	2.9	2.9	0.30	ns
	cohesive	3.8	3.9	0.17	ns
End of semester survey data					
Approaches to study	*surface*	3.4	3.4	0.27	ns
	deep	3.3	3.2	0.54	ns
Conceptions of Biology	*fragmented*	3.0	3.0	0.48	ns
	cohesive	3.8	3.8	0.70	ns
Unit of study evaluation	*clear goals*	3.0	3.0	0.90	ns
	independence	2.6	2.6	0.35	ns
	good teaching	3.0	3.0	0.93	ns
	workload	2.7	2.7	0.56	ns
	assessment	3.2	3.2	0.96	ns