Chapter 6

Results: Relationship between approaches and outcomes

Introduction

The previous two chapters presented the results of this study into learning approaches and learning outcomes respectively, as separate aspects of learning in the specific study context. The function of this chapter is to examine the relationships between these two aspects of student learning, particularly between learning approach and SOLO levels. This is the subject of research theme 3, which was guided by the following three lines of inquiry posed in Chapter 2:

3a. What are the relationships between quantitative measures of learning approaches and examination question outcomes?

3b. Do the relationships between quantitative measures of approaches and outcome differ between internal and external students?

3c. How do the learning approaches that students describe in an interview fit with the quality of their verbal explanations of meiosis?

3a: Relationship between MSPQ responses and learning outcomes: all students

The investigation of the relationship between MSPQ responses and learning outcomes was framed by two research questions, each with a different analytical focus:

3a.i: What are the relationships between MSPQ responses and learning outcomes variables across the whole group?

3a.ii: What are the relationship between MSPQ responses and learning outcomes for groups of students with similar learning approach patterns?

The first question focuses on the relationships between the deep and surface approach variables and the outcome variables (SOLO levels), while the second takes into account the different combinations of deep and surface approaches adopted by students in the study context. This section presents results for these two questions.

3a.i: Relationships between MSPQ responses and learning outcomes variables across the whole group

This subsection presents the correlations between approach and SOLO level achieved in examination question responses, and comparisons of mean deep and surface ability measures between High ($\geq R_2$) and Low ($\leq M_2$) SOLO groups. Relative frequencies of Low and High SOLO levels are shown for banded deep and surface learning approach abilities.

Correlation between approach and outcome variables

Spearman correlation coefficients among and between learning approach and outcome indicators are shown in Table 6.1.

Table 6.1: Spearman correlations between deep and surface approach abilities and SOLO levels and marks in examination questions for all students,

	SOLO level: exam question	Mark: exam question	Deep approach ability
SOLO level: exam question	1		
Mark: exam question	**.71****	1	
Deep approach ability	**.18****	**.15***	1
Surface approach ability	**-.17***	-.07	-.08

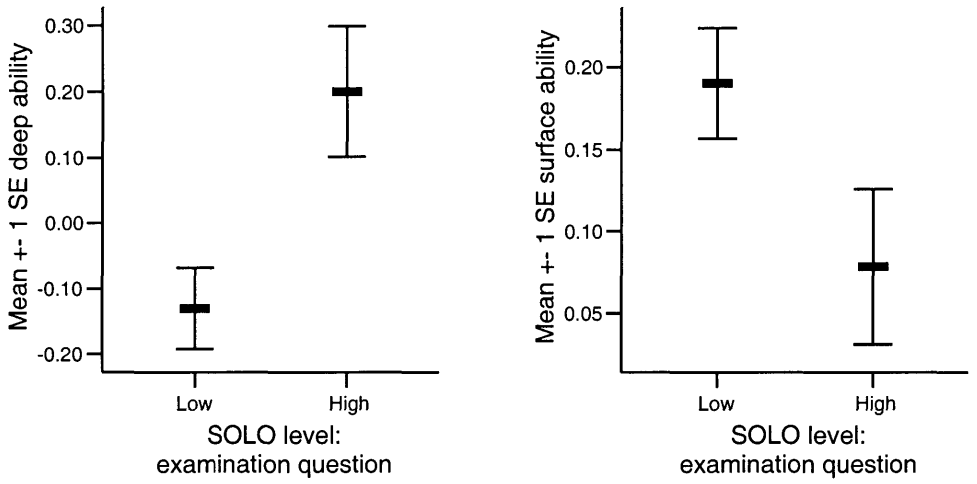
N = 205-301
** Correlation is significant at the 0.01 level (2–tailed).
* Correlation is significant at the 0.05 level (2–tailed).

For the group as a whole, there is a significant, positive but small correlation between deep approach ability and SOLO levels ($r^2 = 0.03$) and marks ($r^2 = 0.02$) in the examination question. Table 6.1 also shows a significant, negative and small correlation between surface approach ability and SOLO levels in the examination question ($r^2 = 0.03$), but not between surface ability and mark. For the whole student sample there is an apparent relationship between learning approach and outcome, with deep approaches associated with better outcomes, and surface approaches associated with poorer learning outcomes. In both cases, though, the relationships are quite weak, explaining only 3% of the variance.

Comparison of mean learning approach abilities between High and Low SOLO groups.

The relationships between approach and outcome suggested by the correlation coefficients were investigated further by comparing learning approaches across

groups of Low ($\leq M_2$) and High ($\geq R_2$) quality learning outcomes as measured by SOLO. Figure 6.1 shows a comparison of the mean deep and surface approach abilities for groups of students responding at Low and High SOLO levels, in the examination meiosis question.



a: Mean deep ability b: Mean surface ability

Figure 6.1: Mean deep and surface abilities for students with Low (≤ M2) and High (≥R2) SOLO levels for examination question responses

As is indicated by Figure 6.1a, mean deep ability was significantly lower for the group responding to the examination question at M_2 or below, than for the group responding at R_2 or above ($t(282) = -2.99$, p=.003), but this was only a small effect ($\eta^2 = 0.03$). The mean surface ability, in contrast, was higher in poorly performing students (Figure 6.1b), although the difference between mean surface ability for the Low and High SOLO groups just failed to reach statistical significance ($t(282) = 1.95$, $p = .052$) and the effect therefore was very small ($\eta^2 = 0.01$). These results corroborate the weak correlations detected between approach and outcome, in suggesting that the group with better learning outcomes had greater use of deep learning approaches and tended towards less use of surface approaches. Again, the small effect sizes suggest that the differences, though significant, are not particularly meaningful.

More descriptive information about the relationship between learning outcome and approaches was obtained by crosstabulating frequencies of Low and High SOLO levels within the five deep and surface ability bands described in Chapter 4.

Relative frequencies of Low and High SOLO levels for banded deep and surface learning approach abilities

The results of the cross-tabulation of deep and surface abilities with Low and High SOLO levels are depicted in Figure 6.2 below in ratio form.

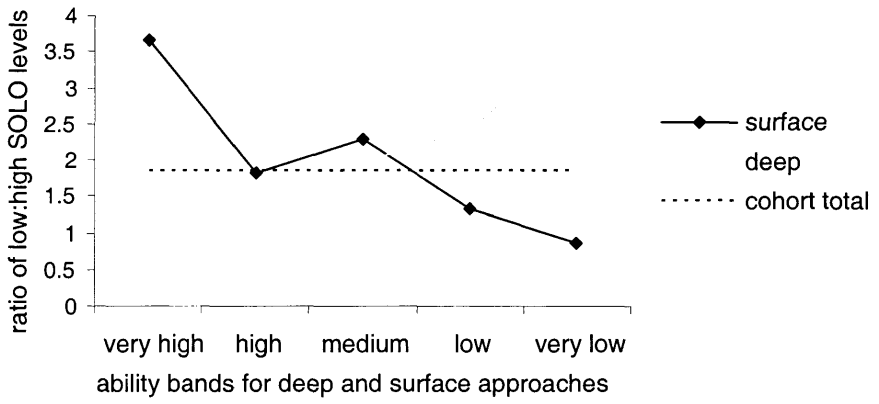


Figure 6.2: Ratio of Low to High SOLO responses for five different bands of surface and deep abilities

As is apparent in Figure 6.2, Low SOLO responses are more frequent overall than High SOLO levels. The cohort total ratio of Low:High SOLO responses is indicated by the dotted line at the point 1.8:1. The bands with markers above the dotted line contain relatively more frequent Low SOLO exam question responses, compared to the total cohort ratio. Conversely, those below the line contain relatively more High SOLO examination question responses. Low SOLO responses are relatively more frequent than High SOLO responses in the two high surface bands, and the two low deep bands.

The differences between Low and High SOLO responses in surface bands are significant only at $p < 0.1$ ($\chi^2(4) = 8.85$, $p = 0.06$), while the tendency is more pronounced in the deep bands ($\chi^2(4) = 9.27$, $p = 0.05$). This again indicates the relationship between approach and SOLO outcome measures, with poorer learning outcomes more likely to be associated with more surface approaches and better outcomes with deeper approaches.

In summary, this subsection has shown weak correlations between deep approaches and better outcomes and surface approaches with poorer outcomes. This finding is supported by significantly lower mean deep ability and a tendency for higher mean

surface ability in the Low SOLO group. More detailed exploration of the frequencies of High and Low SOLO responses in five learning approach bands found congruent trends, which were significant only for the deep bands.

The findings in this subsection are expressed in terms of deep and surface variables in isolation, not in combination. Although this helps to inform the exploration of the relationship between approach and outcome variables, it does not take into account the actual combinations of approaches adopted by students in the study topic. This is the subject of the following subsection.

3a.ii: Relationship between MSPQ responses and learning outcomes for groups of students with similar learning approach patterns

The focus of analysis in this subsection is different groups of students with similar patterns of learning approach. Frequencies of Low and High SOLO levels are shown for students adopting predominantly deep, surface or mixed approaches, and learning outcomes for the learning approach clusters established in Chapter 4 are described.

High and Low SOLO frequencies in different predominant approaches

To examine the relationship between outcomes and predominant approaches for the overall cohort at a broad scale, the banded deep and surface abilities were used to categorise students into three groups of predominantly deep, surface and mixed approaches. A histogram of the number of Low and High SOLO responses to the examination question for each of these approach categories is shown in Figure 6.3.

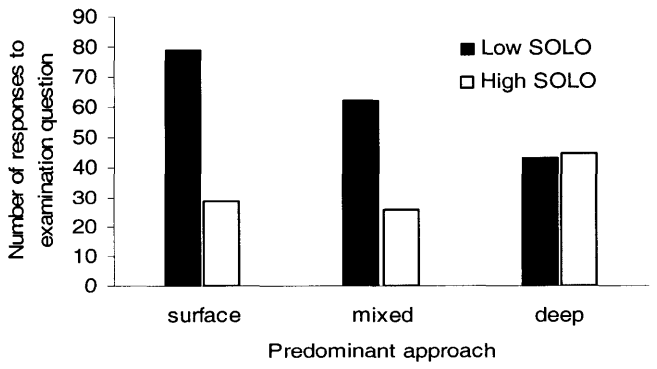


Figure 6.3: Frequency histogram of Low and High SOLO responses to examination question for three predominant approaches to learning

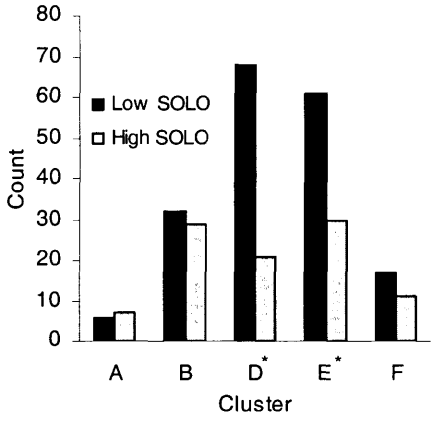
As can be seen in Figure 6.3, High SOLO responses are more frequent than Low only in the group of students reporting a predominantly deep approach (χ^2 (2) =

14.33, $p = 0.001$). This supports the association between deep approaches and better outcomes. It is also apparent in Figure 6.3 that about 30 High SOLO responses were achieved by students using a predominantly surface approach. This indicates that use of a surface approach did not preclude qualitatively better learning outcomes. Likewise, among students reporting predominantly deep approaches, about 40 Low SOLO levels were achieved. This indicates that use of a deep approach was not a sufficient condition for high–quality learning outcomes in the learning context of this study.

Learning outcomes associated with learning approach clusters

This subsection relates learning outcomes achieved to the clusters of learning approaches detected. This provides much finer scale information on the relationship between learning outcomes and approaches based on analysis of groups of students with similar learning approaches.

The major clusters of students which were identified by cluster analysis in Chapter 4 are shown in Figure 6.4 below, together with the frequency of Low ($\leq M_2$) and High ($\geq R_2$) SOLO levels in each cluster.



Cluster	Cluster-mean scores: learning approach variables			
	DM	DS	SM	SS
A	1.6	2.2	-0.2	-0.9
B	0.3	0.4	-0.8	-1
D	-0.8	-0.8	-0.3	-0.1
E	0.6	0.4	0.6	0.4
F	-0.7	-0.7	1.3	1.8

Figure 6.4: Frequency histogram of Low and High SOLO levels across different clusters of students based on learning approach ability measures. Note: * = clusters with a higher ratio of Low:High SOLO levels than the total cohort, i.e, relatively more frequent Low outcomes

The proportion of High SOLO levels across the different clusters in Figure 6.4 is significantly different to the proportion of Low SOLO levels (χ^2 (4) = 11.8, p = 0.02). The clusters in which the ratio of Low:High surface responses is greater than

the cohort total of 1.8:1 are asterisked. In these clusters there are relatively more frequent poor examination question responses, compared to the total cohort ratio.

As is indicated in Figure 6.4, Low SOLO levels are relatively more frequent than High SOLO levels in clusters D and E. These clusters also have the lowest deep ability cluster-mean scores combined with about average surface scores (group D), and a flat profile suggestive of mixed approaches to learning (group E). The greatest ratio of Low to High learning outcomes is in cluster D, which also has the lowest deep ability cluster-mean. This suggests that poorer outcomes are associated with low deep combined with average surface approaches, or with mixed approaches to learning. The outcomes of these two groups are slightly poorer than the strongly surface cluster (F), which has slightly more frequent High SOLO outcomes relative to the entire cohort.

Also evident in Figure 6.4 is that Low SOLO levels are less frequent relative to High SOLO levels in clusters A and B, and to a lesser extent, Cluster F. Two of these clusters (A & B), have roughly equal proportions of Low and High SOLO levels, with a pattern of medium to high deep means combined with relatively low surface means. This suggests that better learning outcomes tend to be associated with high deep combined with low surface approaches, again consistent with previous results in this subsection. The anomalous third cluster (F), as previously mentioned, has a ratio of Low:High SOLO levels which is similar to the entire cohort, in a situation of low deep combined with high surface approaches.

In summary, other than cluster F, these results support the association between predominantly deep approaches and better outcomes, while predominantly surface or mixed approaches tend towards relatively more frequent poorer outcomes. It is also apparent, though, that these relationships do not apply in all cases. Poor outcomes also occur in clusters characterised by high deep and low surface approaches (e.g., clusters A & B), although relatively less frequently. In addition, the group of 11 students attaining High SOLO levels in cluster F is an interesting anomaly to this general pattern, having achieved a relatively high frequency of high–quality learning outcomes despite apparently adopting very low deep and high surface learning approaches.

Summary 3a

In summarising the results of this section, different analyses of the relationship between students' responses to the MSPQ and the quality of their responses to the meiosis question in the examination have lead to relatively consistent conclusions. Correlations between deep approach and better SOLO outcomes and surface approaches with poorer SOLO outcomes are supported by comparisons of mean deep and surface approach abilities across Low and High SOLO levels.

More detailed descriptive examination of the frequencies of Low and High SOLO responses across different deep and surface ability measures provide a similar message. The group of students using a predominantly deep approach had many more High SOLO outcomes relative to the predominantly surface and mixed groups. Finally, the relative frequencies of Low to High SOLO levels in the learning approach clusters generally show relatively more frequent Low SOLO responses in clusters characterised by predominantly surface or mixed approaches.

Also apparent from this section is that although these general patterns and associations appear consistently, they are not particularly strong. The observed correlations between approach and outcome account for very little of the variance, and the effect sizes of comparison of mean deep and surface approaches in Low and High SOLO groups are small. This reflects the finding that some students in bands of highest deep or lowest surface ability measures went against the general trend in producing low quality learning outcomes. Conversely, some students in bands of lowest deep or highest surface ability measures produced high–quality learning outcomes. Similarly, although clusters with predominantly surface or mixed approaches tend to have a relatively higher ratio of poor quality outcomes, one cluster with extremely low deep and high surface ability measures contradicted this trend, with relatively more high–quality learning outcomes.

Nonetheless, although weak, there is a consistent apparent relationship between learning approach and outcome, with better outcomes tending to be associated with predominantly deep learning approaches, and poorer outcomes with surface or mixed approaches.

3b: Relationship between MSPQ responses and learning outcomes: comparison of internal and external students

The comparison of the relationship between MSPQ responses and learning outcomes for internal and external students is presented in response to two research questions. These parallel the research questions in the previous section:

3b.i: What are the relationships between MSPQ responses and learning outcomes variables for internal and external cohorts?

3b.ii: What are the relationship between MSPQ responses and learning outcomes for groups of internal and external students with similar learning approach patterns?

3b.i: Relationships between MSPQ responses and learning outcomes variables for internal and external cohorts

The approach/outcome relationship of internal and external students is compared in this subsection, by correlations between approach and outcome variables and comparisons of means for High and Low SOLO groups for separate internal and external cohorts. Relative frequencies of Low and High SOLO levels for banded deep and surface learning approach abilities are described for both internal and external cohorts.

Correlation between approach and outcome variables

Spearman correlations between approach and outcome measures for internal and external student groups are shown in Table 6.2.

For the internal students, Table 6.2 indicates no significant correlation between deep approach and SOLO level or mark attained in the examination or practical test question outcome. There is a negative correlation between surface approach ability and SOLO levels in the examination question, although this is quite small, explaining only 4% of the variance in SOLO categories (r^2=.04). There is, however, no significant negative correlation between surface approach ability and SOLO levels or marks in the practical test question.

Table 6.2: Spearman correlations between deep and surface approach abilities and SOLO levels and marks for examination and practical test questions; external and internal students

		SOLO level: exam question	Mark: exam question	Deep approach ability	Surface approach ability	SOLO level: prac test question
External students (N = 70-76)	SOLO level: exam question	1				
	Mark: exam question	**.70****	1			
	Deep approach ability	**.32****	**.32****	1		
	Surface approach ability	-.04	-.06	-.09	1	
Internal students (N=204-222)	SOLO level: exam question	1				
	Mark: exam question	**.67****	1			
	Deep approach ability	.12	.09	1		
	Surface approach ability	**-.20****	-.08	.08	1	
	SOLO level: practical test question	**.60****	**.43****	.11	-.12	1
	Mark: practical test question	**.49****	**.52****	.09	-.12	**.74****

** Correlation is significant at the 0.01 level (2–tailed).
* Correlation is significant at the 0.05 level (2–tailed).

By contrast, for external students, Table 6.2 indicates a moderate positive correlation between deep approach ability and SOLO levels and mark in the examination question. This relationship accounts for 11.6 % of the variance (r^2=.116). That this relationship is not evident for internal students suggests that the correlation that was found across the whole group (see Table 6.1 in previous subsection) reflects the stronger relationship between deep approach ability and exam outcome in external students. There is no correlation between surface approach and outcome for external students, which suggests that the correlation that was found across the whole group reflects the relationship between surface approach and exam outcome in internal students.

The differences between internal and external students indicated by these results are that deep ability is related (positively) to learning outcomes in external students, while surface ability is related (negatively) to SOLO measures of learning outcomes of the examination question in internal students. These differences were investigated further by comparing mean deep and surface ability measures across Low and High SOLO groups for internal and external students separately.

Comparison of mean learning approach abilities between High and Low SOLO groups

The results of the comparison of mean learning approach abilities for internal and external students are shown in Figure 6.5 below.

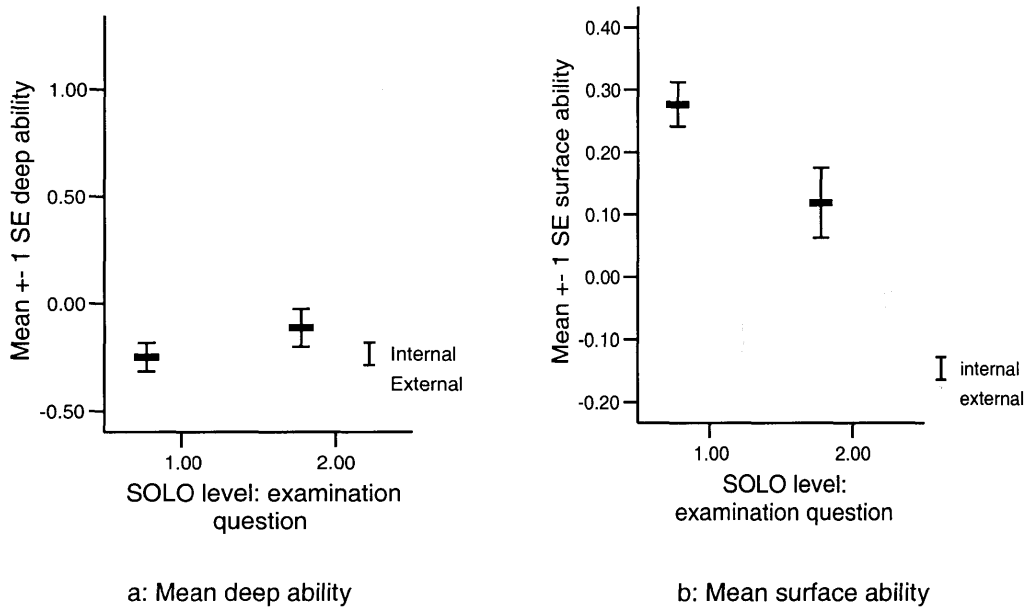


Figure 6.5: Comparison of mean deep and surface approach abilities for groups of Low (1) and High (2) SOLO responses, internal and external students

The results summarised in Figure 6.5 show differences in relationship between approaches and outcomes for internal and external students. In relation to deep approaches (Figure 6.5a), internal students show no significant difference in mean deep ability for the Low and High SOLO examination question responses ($t(210) = -1.221$, $p = 0.22$). This finding is also the case in the practical test responses ($t(203) = -1.1$, $p = 0.29$). By contrast, the group of external students with Low SOLO responses have a significantly lower mean deep ability than their better performing counterparts ($t(68) = -3.16$ $p = .002$), and this effect is reasonably large ($\eta^2 = 0.13$).

The converse applies for surface approaches (Figure 6.5b). For internal students, the Low SOLO group for the examination question has a significantly higher mean surface approach score than the better performing group ($t(210) = 2.47$, $p = 0.01$), and this effect is small to moderate ($\eta^2 = 0.03$). This is not the case, though, in the practical test, where there is no significant difference between mean surface ability of Low and High SOLO groups ($t(203) = 0.8$, $p = 0.43$). There is no significant difference in surface approach detected for the Low and High performing external

groups ($t(68) = -0.73$ $p = 0.47$), who have much lower mean surface scores in any case.

These results indicate that the significant difference in mean deep approach abilities across Low and High SOLO levels which was found for the group as a whole (Figure 6.1), reflects the difference among external students. Internal students have lower deep approaches in general, and show no significant difference between mean deep learning approach across the Low and High SOLO levels in the examination (Figure 6.5a). Conversely, the difference in mean surface approach abilities across Low and High SOLO levels that was found for the group as a whole (Figure 6.1) reflects the difference among internal students. External students have lower surface approaches in general, and show no significant difference between mean surface learning approach across the Low and High SOLO levels in the examination (Figure 6.5b).

Relative frequencies of Low and High SOLO levels for banded deep and surface learning approach abilities

The relative frequencies of Low to High SOLO responses to the examination question in the five deep and surface bands are shown in this subsection for internal and external students separately. In tests of the significance of these frequency data, the two highest and lowest bands were collapsed into one group each, where too many cells had expected frequencies below five.

The distribution of Low and High SOLO levels across the banded surface and deep ability measures for internal students is shown in Figure 6.6.

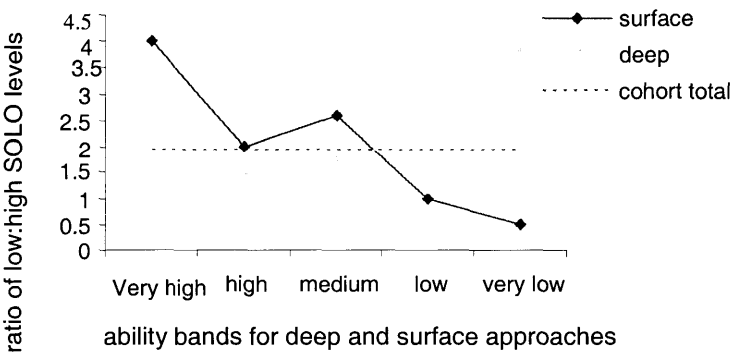


Figure 6.6: Ratio of Low to High SOLO responses for five different bands of surface and deep abilities: internal students

In Figure 6.6, the bands with markers above the dotted line contain relatively more frequent Low SOLO exam question responses, compared to the total cohort ratio. Conversely, those below the line contain relatively more High SOLO examination question responses. As is evident from Figure 6.6, for internal students Low SOLO responses are relatively less frequent in the two lowest surface bands , and considerably more frequent in the very high surface band ($\chi^2(4) = 13.34$, $p = 0.01$). Although there is a trend for Low SOLO responses to be relatively more frequent in the lowest deep band, this is insignificant ($\chi^2(2) = 2.09$, $p = 0.35$).

The distribution of Low and High SOLO levels across the banded surface and deep ability measures for external students is shown in Figure 6.7.

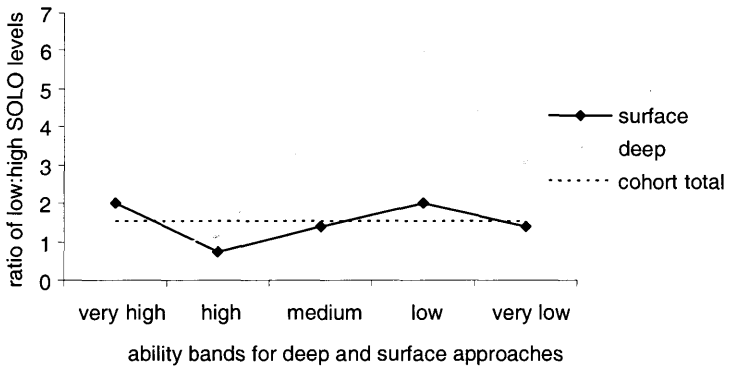


Figure 6.7: Ratio of Low to High SOLO responses for five different bands of surface and deep abilities: external students

Figure 6.7 shows that for external students, Low SOLO responses are relatively more frequent in the medium and two lowest deep bands, and less frequent in the two high deep bands ($\chi^2(2) = 7.44$, $p = 0.02$). There is little apparent relationship between High and Low SOLO level and surface approach in the external students ($\chi^2(2) = 0.67$, $p = 0.71$).

These data suggest that for internal students High SOLO outcomes occur relatively more often than Low SOLO outcomes when little use is made of surface approaches. For external students, High SOLO outcomes occur relatively more often than Low SOLO outcomes when more use is made of deep approaches.

In summary, the correlations, comparison of mean learning approach abilities and frequency of Low and High SOLO levels across learning approach bands all show

one consistent finding. This is that deep approaches are positively related to better SOLO outcomes in external students only, while surface approaches are negatively related to better SOLO outcomes in internal students only. In the following subsection, these differences between internal and external students are examined in the context of the different mixes of learning approach adopted by the students.

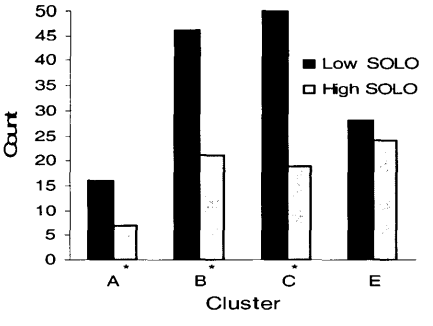
3b.ii: Relationship between MSPQ responses and learning outcomes for groups of students with similar learning approach patterns — internal and external cohorts

In this subsection the learning outcomes achieved by relatively homogenous learning approach clusters of students are outlined, for internal and external students separately. This enables comparison of internal and external cohorts based on their learning outcomes in response to the combination of deep and surface learning approaches exhibited.

Learning outcomes associated with learning approach clusters

The frequencies of Low and High SOLO outcomes for the different major clusters of internal and external students are shown in Figure 6.8 and Figure 6.9. Clusters of fewer than five students are excluded from these figures to assist interpretation. Clusters in which the ratio of Low:High outcomes is higher than for the cohort total are asterisked. In these clusters there is a higher proportion of Low SOLO responses relative to High compared to the whole cohort, therefore the asterisked clusters contain proportionately more frequent poor exam question responses, compared to the total cohort ratio.

The frequency of Low and High SOLO levels for different clusters of internal students is shown in Figure 6.8.

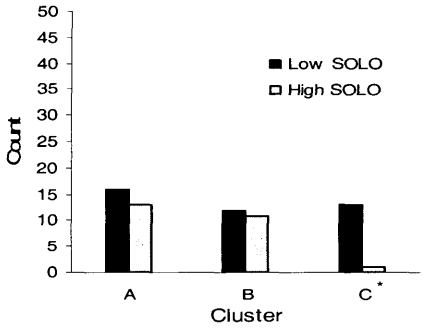


Cluster	Cluster-mean scores: learning approach variables			
	DM	DS	SM	SS
A	-0.8	-0.6	1.4	1.9
B	0.4	0.4	0.5	0.5
C	-0.8	-0.9	-0.2	0.0
E	0.1	0.2	-0.7	-0.8

Figure 6.8: Frequency histogram of Low and High SOLO levels across homogeneous clusters of internal students based on learning approach ability measures. Note. * = clusters with a higher ratio of Low:High SOLO levels than the total cohort.

For internal students (Figure 6.8), in clusters A, B and C the ratio of Low:High SOLO levels is higher than for the entire internal cohort. The ratio of Low:High SOLO responses for the internal cohort is 2:1.The predominant approaches identified in clusters A, B and C, according to the cluster-mean scores, are surface and mixed. Only cluster E has relatively more frequent High SOLO responses and that cluster shows a predominantly deep approach, with about average deep combined with very low surface means. This is consistent with previous results linking High SOLO responses with low surface approaches for internal students, although the difference in frequencies in this case is not statistically significant (χ^2 (3) = 5.06, p = 0.17).

The frequency of Low and High SOLO levels for different clusters of external students is shown in Figure 6.9. The ratio of Low:High SOLO responses for the external cohort is 1.5:1.



Cluster	Cluster-mean scores: learning approach variables			
	DM	DS	SM	SS
A	0.9	0.5	0.5	0.2
B	1.2	1.4	-0.8	-1.2
C	-0.9	-0.4	-0.9	-0.8

Figure 6.9: Frequency histogram of Low and High SOLO levels across homogeneous clusters of external students based on learning approach ability measures.: Note: * = clusters with a higher ratio of Low:High SOLO levels than the total cohort.

For external students (Figure 6.9) the relationship between SOLO level and cluster is statistically significant (χ^2 (2) = 7.18, p = 0.03). The only cluster with a Low:High SOLO ratio that is markedly different from the ratio for the external cohort is Cluster C. This cluster has a ratio of Low:High SOLO levels that is extremely high, and this cluster has a very flat profile of low deep combined with low surface approaches consistent with students adopting little of either approach to learning. Clusters A and B have somewhat more frequent High SOLO responses relative to the cohort ratio. Although in both of these clusters deep cluster means are higher than surface means, Cluster A also has a relatively flat profile with little difference between mean deep and surface scores. This is consistent with mixed approaches to learning, although

the mean deep and surface abilities are notably higher than in Cluster C. Cluster B has a learning approach profile of very high deep and low surface approaches.

The relatively high frequencies of poor responses in cluster C suggest strongly that poor outcomes are linked to a combination of essentially neither approach to learning. That better responses occur most frequently in cluster B suggests that for external students better SOLO outcomes are linked to predominantly deep approaches. The results in cluster A are not particularly conclusive, but suggest that a Low:High SOLO response ratio that is still below the cohort total can be achieved by a group of students reporting essentially mixed deep and surface approaches.

In summary, the results of the cluster analyses provide a more realistic picture of the patterns of relationships between learning approaches adopted by students, and the quality of outcomes they achieved. For internal students, better responses occurred most frequently in a group of students (E) showing a predominantly deep approach, with about average deep combined with very low surface means. For external students, better responses occurred most frequently in a cluster (B) of students with predominantly deep approaches.

Summary 3b

This section has highlighted some differences in the relationship between approach and outcome for internal and external students, which are summarised in Table 6.3.

Table 6.3: Summary of differences in relationship between approach and outcome for internal and external students.

Enrolment	Relationship between surface approach (S) and outcome	Relationship between deep approach (D) and outcome
Internal	• Small –ve correlation • Mean S approach for Low outcome group significantly greater than for High outcome group • High SOLO levels relatively more frequent in low bands	• No correlation • No significant difference between mean D approaches of Low & High outcome groups • No significant difference in frequency of SOLO levels across bands
	• Proportionately more High responses in cluster E with low S & medium D mean approaches (though difference not significant)	
External	• No correlation • No significant difference between mean S approaches of Low & High outcome groups • No significant difference in frequency of SOLO levels across bands	• Moderate +ve correlation • Mean D approach for Low outcome group significantly less than for High outcome group • No significant difference in frequency of SOLO levels across bands
	• Proportionately more Low responses in cluster with low S & D means (cluster C), most High responses in cluster with high D & low S means (cluster B)	

Table 6.3 shows that, in general, there is a negative association between surface approaches and outcome variables only in internal students, with no association between these two variables for external students. There is a positive association between deep approach and outcome only for external students, with no association between these two variables for internal students. For internal students the cluster with low surface and medium deep mean approaches has proportionately more High responses. In contrast, for external students the cluster with low surface and low deep means has proportionately more Low responses, and the cluster with high deep and low surface means has the most High SOLO responses.

The correlation between deep approach and outcome in external students is moderately strong, and the significantly greater mean deep approach in the High SOLO group within the external cohort had a reasonably large effect size. The other correlations account for little of the variance, and the significantly greater mean surface approach in the Low SOLO group within the internal cohort had a small to moderate effect size. Again, this reflects the fact that both high and low–quality learning outcomes are apparent in the extreme surface and deep ability bands.

Although a number of trends are identified in cross-tabulations of frequency of Low and High SOLO categories across different approach bands and clusters, some of these did not reach statistical significance. Nonetheless, these general differences that were found are relatively consistent across several ways of looking at the data, and appear to reflect real differences between the relationship between learning approaches and outcomes of the internal and external students in this study. The relationships between learning approaches and outcomes as expressed in interviews are outlined in the following section.

3c: Relationship between learning approaches and outcomes expressed at interview

The initial hypothesis for the relationship between learning approach and outcome as outlined in Chapter 2 was that surface approaches would be associated with Low SOLO outcomes ($\leq M_2$) and that deep approaches would be associated with SOLO codes at or above R_2. This hypothesis led to the first two of the three specific research questions that were used to follow this line of inquiry. These are:

3c.i: Do students describing a surface approach describe meiosis in a way consistent with the Low SOLO (≤M2) group of responses?

3c.ii: Do students describing a deep approach describe meiosis in a way consistent with the High SOLO (≥R2) group of responses?

3c.iii: How does the relationship between written responses to meiosis questions and the interview explanations relate to the learning approach described by the students?

Table 6.4 provides a summary of the learning approach and outcome findings from the students' interviews that were discussed more fully in Chapters 4 and 5. This table informs all three questions examined in this section.

Table 6.4: Summary of learning approaches and outcomes from student interviews

Student	Internal/ External	Age	Learning approach from interview	Learning outcome from interview: understanding of meiosis	SOLO group	Interview compared to practical test responses	Interview compared to examination question responses
Alex	I	19	Surface	M_1	Low	worse	same
Amanda	E	21	Surface	M_2	Low	-	worse
Liam	I	18	Surface	M_2 (- R_2)	Low	worse	worse
Kim	I	18	Surface	M_2 (- R_2)	Low	same	worse
Jenni	I	18	Surface	M_2 (- R_2)	Low	worse	same
Tina	I	18	Surface	M_2	Low	same	-
Charlie	I	21	Surface	R_2	High	worse	worse
Ruth	I	18	Surface	M_{1F}	High	better	same
Tom	I	19	Mixed	M_2	Low	better	better
Ryan	I	20	Mixed	R_2	High	same	better
Adam	E	35	Deep	At least M_2	Low?	-	?
Laura	I	19	Deep	M_{1F}	High	same	better
Jacinta	E	58	Deep	R_{1F}	High	-	better
Rob	E	33	Deep	R_{1F}	High	-	better
Kirsty	I	19	Deep	R_2 (-R_{1F})	High	same	better
Paul	E	44	(Deep but no evidence -tape malfunction)	M_{1F}/R_{1F}	High	-	worse

Note: SOLO categories in parentheses indicate level achieved after prompting

3c.i: Outcomes of students describing a surface approach

As can be seen from Table 6.4 , six of the eight students who described their learning in ways consistent with a surface approach achieved learning outcomes in the Low SOLO group. One of these students provided an illuminating account of how her surface approach was manifested in answering examination questions:

> S: Someone once told me that, like with exam questions like this, it's not so much about what you write it's whether you use the key words. So if you know which key words like you just think you know, with each, like you know, really stuffed–up term like meiosis, which is fairly complicated, there's a whole lot of basic terms which explain it, which if you can get those terms — if you know them — you include them and you write a sentence about them — that's pretty much what you do. So just try to think about the terms you're supposed to write down, and then write a sentence on them
> I: So that's what you were trying to do when you were answering that question? You were trying to get the key words down?
> S: Yeah, like haploid, diploid, the processes and chromatids basically and chromosomes. I knew those words had to be in there somewhere so I wrote them down.
>
> (Tina)

For Tina and most other students adopting a surface approach, the intention to reproduce and learning focus at the "sign" rather than the "signified" associated neatly with responses that did not integrate the elements of meiosis into a relational answer, although three of the students reporting a surface approach developed an R_2 explanation of meiosis after some limited prompting. In general, for the students taking a surface approach, relational understanding was not sought and therefore was not achieved.

Two students (Charlie and Ruth) were the exception to the surface approach — poor outcome relationship. Both of these students achieved outcomes in the High SOLO group despite reporting surface approaches to learning. Chris had done meiosis at first–year university level previously:

> S: I'm doing first and second year, I've actually done a year and a half of my degree in Perth at Murdoch University, so I've only got accredited for about 6 months of my degree over here. The units are very different. I've done all the Biology before basically and they haven't given me any of it over here...
> I: Given that, you've probably done meiosis before?
> S: Yeah. I've done that. I think we did a bit in Biology in high school as well as in first–year Biology at Murdoch. So I've done that.

Ruth also had a strong background in the topic area:

> I: So when have you done anything about meiosis before — apart from this semester?

> S: Year 12, year 11, year 10, year 9, a bit in year 8 probably. I can't remember back that far, but most likely
> I: And did you do it in Biology 110?
> S: Yeah, I think I did.
> I: How much of a handle do you think you had on it before you actually started this unit?
> S: I know what's happening.
> I: And how do you know all that stuff you've done?
> S: By doing it for the last 4 to 5 years.

It seems likely that background knowledge may have contributed to the relatively high–quality learning outcomes achieved by Charlie and Ruth.

Two students reported mixed approaches to learning at interview. Of these, Tom achieved an outcome in the Low SOLO group, while Ryan's explanation of meiosis was in the group of high–quality responses. Interview transcripts of these two students did not contain additional details that further informed the relationship between their learning approaches and outcomes. As only two students reported mixed approaches to learning at interview, little can be concluded about the relationship between their learning approach and outcome from the available information.

In summary, with the exception of two students who had a very strong background in meiosis, the students who expressed a surface approach to learning had Low SOLO outcomes ($\leq M_2$). This finding is consistent with the initial hypothesis.

3c.ii: Learning outcomes of students describing a deep approach

Of the five students reporting a deep approach to their learning in their interviews, four exhibited understandings of meiosis at interview which were consistent with High SOLO categories. For one student (Adam), the interview transcript could not be coded more precisely than M_2 as it was unclear whether or not Adam could integrate the elements of meiosis that he had mentioned into an R_2 response. In general, of the interviewed students, deep approaches were associated with High ($\geq R_2$) SOLO categories, as was predicted in the initial hypothesis.

In summary, the students describing a deep approach sought understanding, focused on the "signified" as well as the "sign", and in most cases achieved a relational understanding of meiosis that could be articulated at interview.

3c.iii: Comparison of written responses, interviews and learning approaches

The students' responses to the practical test questions preceded their interviews by a week or so. Because of this relatively close temporal proximity, comparing the relative stability of the responses in these two contexts to the learning approaches adopted was of interest. As can be seen in Table 6.4, the four students who performed worse in their interview description of meiosis than in the preceding practical test all had described taking a surface approach to their learning. One parsimonious explanation for this is that the surface approach that these students adopted in the topic resulted in a relatively superficial understanding and short–lived ability to describe the process of meiosis.

Two students, however, performed better in the interview than in the practical test, despite having adopted a surface (Ruth) or mixed (Tom) approach to their learning. However, as described in Chapter 5, both Tom and Ruth seem to have had underperformed in the test. Tom had left the meiosis question till last following a "mental blank", and Ruth had interpreted the question as asking for a broad definition. So in these two cases the better performance in the interview may have reflected their understanding of meiosis more accurately than the practical test.

The other aspect of interest in the relationship between written and verbal explanations of meiosis questions and learning approaches relates to the responses to the examination question. As can be seen from Table 6.4, none of the students who described their learning approaches as surface provided better explanations of meiosis during interview than in their much later written responses to the examination question. This situation broadly parallels the findings from the practical test. So, in general, the students reporting a surface approach provided better explanations of meiosis in written responses to the practical test and examination questions than was apparent in their verbal responses. This finding is in contrast to the five students who described their learning in a way consistent with a deep approach. All but one of these (Adam) described their understanding of meiosis better during interview than they did in their written responses to the later examination question.

In summary, students reporting a surface approach generally could not explain meiosis at interview to the same SOLO level as they achieved in written responses to the practical test and examination questions. Conversely, most of the students reporting a deep approach could explain meiosis better in interview than in written responses to assessment questions.

Summary 3c

In general, the interview data tend to support the initial hypothesis, with surface approaches associated with SOLO codes less than or equal to M_2, and deep approaches related to SOLO codes at or above R_2. Most of the students who reported using a surface approach could outline many of the elements of the 2nd cycle, concrete–symbolic mode, but could not integrate them into a coherent, structured account that described the movement of the chromosomes in the process of meiosis. The only exceptions to this were two students with particularly strong backgrounds in meiosis. Most of the students who reported a deep approach did integrate the elements of the 2nd cycle, concrete–symbolic mode into a relational account of meiosis, and some could go further and relate the elements of the formal mode.

Investigation of the relationship between interview and written explanations of meiosis in the context of students' learning approaches elucidated further information. In general, students reporting surface approaches to their learning performed better in written responses to test questions than in verbal explanations of meiosis. In contrast, students reporting a deep approach to their learning in the topic performed worse in their written responses to test questions than in verbal explanations during interview.

Overview

Findings from both the quantitative and qualitative data in this chapter support the hypothesised relationship between learning approaches and outcomes in the naturalistic context of students' learning and assessment in a particular first–year biology topic. Both quantitative and qualitative data showed that deep approaches were associated with better outcomes and surface approaches with poorer outcomes. Also apparent from the results presented in this chapter is that these general patterns and associations are consistent in quantitative data, but are not particularly strong.

The first line of inquiry in this chapter (3a) related to the relationship between MSPQ responses and examination question responses. Quantitative data described in answer to this issue indicated a weak correlation between deep approaches and better outcomes and surface approaches with poorer outcomes. In addition, mean deep ability was significantly lower for the group with Low SOLO outcomes than for the High SOLO group, while mean surface ability was higher in the Low SOLO group than in the High SOLO group. Finally, Low SOLO responses were relatively more frequent in clusters of students characterised by predominantly surface or mixed approaches.

The second line of inquiry in this chapter (3b) was to compare the learning approach/outcome relationship for internal and external groups. The relatively large number of students sampled for the quantitative data enabled these comparisons to be made. There was a negative association between high surface approaches and High SOLO outcomes only for internal students, and a positive association between deep approach and outcome only for external students. This difference was generally supported by the qualitative data.

The final line of inquiry in this chapter (3c) was the relationship between learning approach and outcome data from student interviews. All the interviewed internal students with a surface approach did have Low SOLO outcomes, except for the two with considerable background in meiosis. The single external student who reported a surface approach also had a Low SOLO outcome. Likewise, all the interviewed external students with a deep approach for whom full information was available did have High SOLO outcomes. The two internal students who reported a deep approach also had High SOLO outcomes.

Overall, the results from the two methodological perspectives provide congruent and complementary information. The interviews provided rich, detailed, case–based information on students' learning approaches and outcomes, which complemented the broader scale more generalisable information from the MSPQ responses. In addition, the additional detailed information that was available from the interviews assisted interpretation of the results in some cases (for example Charlie and Ruth), enabling apparently contradictory findings to be reconciled.

This chapter and the two preceding chapters have presented the results of the three study themes of students' learning approaches, outcomes, and the relationship between these two components of the 3P model. The following chapter discusses the results of these three themes in the context of previous research into student learning in higher education, in particular, in learning tertiary science.

Chapter 7

Discussion

Introduction

This chapter provides a general discussion of the results presented in the preceding three chapters. Each of the three themes of the study is discussed in the context of relevant previous research, beginning with students' approaches to learning, then their learning outcomes and, finally, the relationship between students' learning approaches and outcomes.

Theme 1: Approaches

This section discusses the results relating to students' approaches to learning. The lines of inquiry that guided this theme related to the learning context, students' responses to the MSPQ, their interview responses, and the relationship between the quantitative and qualitative indicators of learning approach. Within these lines of inquiry were specific questions comparing learning approaches of internally and externally–enrolled students. In this section, each of these lines of inquiry is discussed in turn.

1a: Characteristics of teaching and learning context

Investigation of students' learning approaches began by examining the learning context and students' perceptions of their learning context, as a background against which to view to the learning approaches adopted by students. In this subsection, a précis of the results relating to the learning context is provided, followed by a discussion relating these study findings to previous relevant literature.

Précis of results

The learning and teaching contexts, for internal and external students, included traditional lecture format together with practical activities designed to illustrate and assist understanding of the concepts already presented in lectures. Internal students had more regular face-to-face contact with lecturers. External students studied mostly at home from print–based materials, with a compulsory five–day residential

school comprising lectures and practicals similar to those experienced by the internal students.

All student focus groups reported general satisfaction with the broad teaching format and the amount and difficulty of the content. Although the large amount of content was recognised by the lecturers, many of the students either accepted the content simply as "that's the way it is at uni", or commented that they had done it before at school. In many other respects, though, the students' perceptions of their contexts differed across the internal and external cohorts. Many internal students were dissatisfied and bored with the practical sessions and some wanted more direct application of the content to their degree program. Most external students in the focus groups enjoyed the practical sessions and found the course content personally relevant to them.

Discussion

Many characteristics of both the internal and external contexts of this study are consistent with traditional large introductory science units. A particular issue is the "huge amount of content" (Lecturer 1) in the unit and topic at the focus of this study. One of the challenges in first–year biology units is the breadth and continually expanding nature of scientific knowledge (Hounsell & McCune, 2002), as well as the hierarchical nature of scientific concepts. Mastery of scientific concepts often begins from an initial understanding of the details of subordinate concepts (Ramsden, 1984, p. 157). The need for a broad base of knowledge for later understanding of biology has been explicitly recognised in benchmarking documents for the biosciences (e.g., Quality Assurance Agency for Higher Education, 2002, cited in Hounsell & McCune, 2002, p. 5). Hence, a wide range of basic concepts is presented in many introductory science units (for reviews see Hegarty-Hazel, 1990; Prosser & Trigwell, 1999) in order to equip students for later more complex or specialised units of study.

One of the common consequences of this breadth of introductory biological concepts is content overload in first–year units. It has been argued by Ramsden (1992, p. 137) that excessive content in the curriculum is a manifestation of the "mythology" of the teaching as transmission theory. An example of this transmission view of science teaching has been provided by Dunbar (1995): "in the sciences you need an

information pack before you can start to discuss anything, and those tools may have to be acquired by rote-learning before we can do anything with them" (p. 181).

Although attempts may be being made to reduce content in first–year introductory curricula to allow students more opportunity to construct meaningful knowledge, this is problematic. As a headline in *Science* has put it, "information overload hampers biology reforms" (Stokstad, 2001), and expectations to cover large amounts of content have been recognised as one impediment to curricular innovations aimed at inclusive undergraduate science education (Bianchini, Whitney, Breton, & Hilton-Brown, 2001, p. 64). Concerns about "dumbing down" illustrate the continuing tension between breadth and depth of curriculum coverage in first–year science units.

The characteristics of the study context described in Chapter 4 have little in common with even relatively conservative social constructivist approaches to science teaching that have been described by many researchers (e.g., Driver et al., 1994; Hand et al., 1997; Matthews, 1998; Solomon, 1989). The teacher–centred and factual lectures, illustrative practicals and test–based assessments contrast with constructivist characteristics of student collaboration, discussion and reflection which are linked to authentic, problem–solving tasks and facilitated by the teacher. For external students, the social component of the unit was even further compressed into an intensive five–day residential school, which left little time for sharing and constructing meanings. Although constructivisms have been heralded as having a major influence on science education (Matthews, 1998, p. 2), their influence is not strongly apparent in the study context. This situation does not appear to be unique, for example Arlidge (2000, p. 45) claimed that the supposed hegemonic position of constructivism is more theoretical than true in practice for post-secondary education.

The results of this study clearly highlighted differences in perceptions of internal and external students. Unlike the external cohort, many of the internal students found the topic boring and irrelevant. Their perceptions strongly echo claims of the "custom–built irrelevance" (Lowe, 1994) and "crippling" (Herreid, 2001, p. 88) nature of introductory science units, that stifle student interest and hinder learning by transmission of excessive content and illustrative practicals. The boredom expressed by many internal students, who by the end of the day just wanted "to get out" of the practicals (and in fact did so before the scheduled time) was a clear illustration of the

"boring recipe–following" disadvantage cited by Hegarty-Hazel, Boud, and Dunn (1987). Many students, despite expressing boredom, also acknowledged that the exercises clarified their understanding of meiosis, hence the practicals apparently had the advantage of assisting students to improve their basic knowledge. These reactions to the practical were consistent with the advantages and disadvantages of such "controlled exercises" practicals cited by Hegarty-Hazel, Boud, and Dunn (1987).

The negative perceptions of many internal students are also likely to reflect their strongly–held instrumental views about the purpose of tertiary education, which were expressed in interviews. The instrumental concerns are corroborated by the fact that the most readily endorsed item on the MSPQ, by a very large margin, was item 9: "whether I like it or not, I can see that doing well in this section is a way for me to get a good grade in the unit". This stance is perhaps an example of the "New Right" phenomenon described by Arlidge (2000, p. 42) where tertiary students expect teachers to "fill them up" with content so that they can pass examinations and gain the expensive qualifications and subsequent job prospects that they desire. It also concords with the suggestion by Laws (1996) that "relatively few undergraduates are primarily interested in scientific study for its own sake" (p. 25).

Nonetheless, some students in this study, especially but not only those from the older, external cohort, did find personal relevance and interest in the topic and in the practical work associated with it. This suggests that there may have been a maturational aspect of students' learning which interacted with the context. This would be consistent with many studies showing that mature–aged students engage more fully than their younger counterparts in their first–year university studies (e.g., Krause, Hartley, James, & McInnis, 2005, p. v.; Richardson, 1994b).

The characteristics of the internal mode of heavy content and assessment emphasising recall, and the widely perceived irrelevance amongst younger, internal students are theoretically linked to surface approaches (Ramsden, 1992, p. 81). Characteristics of the context such as content, assessment and teaching style which theoretically favour surface approaches applied also to external students. In addition, these students also had considerably less social interaction and feedback from teaching staff. One major difference between the contexts was in the way it was perceived by students. Many external students saw the content as personally relevant,

which is theoretically linked to deeper approaches to learning (Ramsden, 1992, p. 81).

In summary, this subsection has described the characteristics of the learning context experienced by the students, their perceptions of different aspects of their learning environment, and how these relate to previous relevant studies. Some differences between the perceptions of the internal and external cohort about their learning contexts are apparent. This is essential background for exploring the approaches students adopted, which forms the focus of the following subsection.

1b: Students' responses to the Learning Approaches Questionnaire (MSPQ)

The similarities and differences between the teaching and learning contexts, and the students' perceptions of them outlined above, form the background against which the students' learning approaches are viewed. The learning approaches adopted by students in these contexts were investigated from a nomothetic perspective using the MSPQ. In this subsection a précis of the results pertaining to students' responses to the MSPQ is provided. These results are then considered in the light of relevant previous studies into this aspect of tertiary student learning.

Précis of results

The reliability and validity of the MSPQ for students in this study was supported by a range of analytic techniques, including factor analysis, Cronbach's alpha and Rasch measurement analysis. In terms of the relationship between variables, deep and surface approach scores were uncorrelated, suggesting that deep and surface constructs as operationalised by the MSPQ are independent ways by which students approach their learning. Students found it easier to endorse items pertaining to strategies than to motives.

The cluster analysis of standardised ability estimates showed that about 30% of the students endorsed deep and surface items of the MSPQ to a relatively similar extent. This implies use of both deep and surface approaches (mixed approaches) in the study context. Another 30% of the cohort showed moderate surface approaches, 25% reported moderately deep approaches, and only about 5% reported strongly deep approaches to their learning. The groups reporting deeper approaches comprised

older, externally enrolled students, while groups characterised by more surface approaches comprised mostly internally enrolled, younger students.

Comparison of internal and external students showed that the external group reported significantly greater use of deep approaches than internal students, and significantly less use of surface approaches. Cross age-group comparisons showed that students younger than 22 years reported significantly lower deep approach measures and significantly higher surface measures than those 22 years or older. The effects of enrolment type (internal vs external) and age could not be separated by between–groups comparisons. The cluster analyses of external students showed that 40% of the cohort reported mixed approaches to learning, 35% of the cohort reported predominantly deep learning approaches and 20% reported little use of either approach. Of the internal cohort, about 30% reported mixed deep and surface approaches, 30% had adopted somewhat surface approaches, 10% strongly surface approaches and around 10% moderately deep approaches.

Discussion

Results of factor and rating scale analyses of the MSPQ, which supported the reliability and validity of its deep and surface scales, are consistent with much previous research on versions of the SPQ. The reliabilities found for the deep and surface scales of the MSPQ are consistent with previous studies using the SPQ and acceptable for group comparisons (Watkins, 1998, p. 131). They also accord well with a previous topic–level study using the MSPQ in a first–year science context (Prosser et al., 1994, p. 308). The lower reliability on the surface scale is also consistent with literature norms (summarised by Watkins, 1998, p. 132). The construct validity of the deep and surface scales was supported reasonably well by the two–factor solution to factor analysis of the MSPQ, and factor scores from previous applications of the MSPQ have been used in a number of studies (e.g., Crawford et al., 1998a, 1998b; Hazel et al., 2002; Prosser et al., 1994; Trigwell et al., 1999). Separability and fit measures from the rating scale analysis provided further evidence that the constructs of deep and surface learning approaches in the MSPQ have acceptable reliability and validity.

The finding of this study that strategy items were easier to endorse than motives agrees with a similar finding of Waugh and Addison (1998, p. 104-105). They found

that reverse scored surface "behaviour" items of the ASI were harder to endorse, implying that if scored positively, as in this study, the items would have been easier to endorse. It was pointed out by Waugh and Addison (1998, p. 104-105) that a drawback of the ASI was that attitude and behaviour items were unevenly distributed across the deep and surface scales. The differences in motive and strategy item difficulty estimates found in this study suggest that this issue needs to be taken into account in the design and interpretation of approaches to learning scales.

The absence of any correlation between deep and surface scales of the MSPQ in this study reflect the assumption of independent deep and surface dimensions within the development of the SPQ (Biggs, 1979, p. 383). They also support many previous examples of the independence of these two approaches to learning using similar instruments (e.g., O´Neil & Child, 1984, p. 232; Richardson, 1994a, p. 464). The results of students' responses to the MSPQ in this study, like others using versions of the SPQ, support neither a dichotomous relationship between deep and surface as originally articulated by Marton & Säljö (1976a, p. 7), nor a continuum between rote and meaningful learning as proposed by Novak (1998, p. 20). The absence of any correlation between deep and surface scales of the MSPQ also contrasts with the positive correlation found between transformational and reproductive learning by Thomas and Bain (1984).

Variations in patterns of learning approaches

This study identified clusters of students with a number of combinations of learning approaches, including 30% of the total cohort with aspects of both deep and surface approaches. Bearing in mind the likely impact of response sets, the large proportion of students with more-or-less mixed approaches to learning identified by the MSPQ, as opposed to relatively "pure" deep or surface approaches, is theoretically consistent with the independence of the deep and surface scales (Biggs, 1979, p. 383).

There are conflicting views in the literature on the practical likelihood of mixed approaches to learning. Ramsden (cited in Thomas & Bain, 1984, p. 237) suggested that simultaneous use of deep and surface strategies is possible but joint deep and surface motivation unlikely. This contrasts with Biggs' (1987, p. 12) suggestion that joint use of deep and surface strategies was "difficult to see", but motivation to reproduce detail and seek meaning was likely. Use of both deep and surface

strategies is consistent with the suggestion by Thomas and Bain (1984, p. 237) that a dichotomous classification of learning approaches did not reflect "the normal mix of activities used by students". While Prosser and Trigwell (1999, p. 84) argued that "most students are likely to adopt elements of either a deep or surface approach to learning", they also stated (p. 96) that some students "adopt an approach that contains elements of both or neither approach". The latter has been found in a number of previous studies (e.g., Prosser et al., 1996, p. 674).

Some students in this study clearly expressed joint deep and surface motivation, for example:

> "I was trying to remember it for the prac. test so I'd know what to write, and then I just sort of wanted to know what was going on" (Ryan).

Likewise, mixed strategies of memorising before and after understanding were evident:

> "So you've got to understand the information to like put it down on the paper...understand it you've got to know how to write it and produce in the test form" (Tom).

It would seem quite plausible for students to adopt a range of deep strategies when studying a topic as a consequence of personal interest, together with surface strategies aimed at passing tests and gaining the instrumental rewards they want. This accords with Biggs' (1993b, p. 7) description of surface approaches as the "institutional creation" of a commodified tertiary system.

The finding in this study that 20% of the external students reported essentially no approach to learning is of concern, but again not inconsistent with previous research. A study of second–year medical students at the University of Melbourne found that 14% of the cohort adopted neither approach to their study of anatomy (Eizenberg, 1988, p. 183). Prosser, Hazel, Trigwell, and Lyons (1996, p. 674) found that 42% of a first–year physics class were in a cluster characterised by, among other things, adoption of neither deep nor surface approaches to learning. The pattern of no approaches to learning was not so evident in internal students in this study. The 30% of the cohort defined as showing moderate surface approach came quite close, though, with surface mean scores not a great deal higher than deep mean scores.

Differences between external, older cohort and internal, younger student cohort

The results of this study clearly indicate that older students and external students reported more use of deep approaches and less use of surface approaches than the younger and internal students. These differences are likely to reflect at least in part more stable presage factor of learning orientations.

In terms of the 3P model outlined in Chapter 1, the students' approach to learning, which is a context–specific interaction between the students and their learning environment, is also related to their learning orientation, which is a more stable characteristic of the students (Biggs, 1993b, p. 6; Prosser & Trigwell, 1999, p. 39). This has also been termed the "preferred" learning approach (Biggs et al., 2001, p. 136). It has consistently been found that deep orientations are more common in mature–aged students, and surface orientations less common (e.g., Hattie & Watkins, 1981; Richardson, 1994b, 1998; Zeegers, 1999, 2001). It seems, then, that the learning approaches adopted by students in this study may partially reflect this more or less "stable" component of learning orientation which is related to their age. This is in agreement with the suggestion by Biggs, Kember, and Leung (2001, p. 137) that responses to the SPQ reflect characteristics of individuals as well as the context of their learning.

From a different perspective, it is of interest that the external cohort reported more use of deep and less use of surface approaches to learning on the MSPQ. This cohort, in general, interacted with the learning context in such a way as to result in greater use of deep approaches to learning. This was despite the relative isolation from peers and teaching staff.

A multitude of presage variables such as age, full or part–time status, work and family commitments doubtless contributed to the way that individuals within the external cohort approached their learning, as would have their perceptions of their learning context (Prosser & Trigwell, 1999). The absence of practical test may also have influenced the approach these students reported on the MSPQ. Nonetheless, the interactions of the external students with their learning context seem to have resulted in deeper learning approaches that should theoretically be related to higher–quality learning outcomes (Ramsden, 1992, p. 61).

The paucity of younger, internal students adopting a deep approach is of interest in the light of Haggis's (2003) critical appraisal of the relevance of the 3P model in mass higher education, particularly its approaches to learning component. Haggis (2003, pp. 97-99) questioned the extent to which students in a mass system want to engage with and be interested in their subjects, be curious, ascribe to such aims of tertiary education as "discovering, questioning, and creating knowledge", and the extent to which they have the confidence and skills needed to engage with the expectations of the tertiary system. She argued that learners may have many personal and cultural reasons for not engaging with higher educational institutional agendas, and quotes a previous claim that "'it is 'only the best students' who will learn in the ways valued by academics...' the rest frequently learn superficially without understanding" (Elton, 2001, quoted by Haggis, 2003, p. 99).

That the younger, internal cohort in this study reported so little use of deep approaches to learning affords some support to these suggestions. This does not mean, though, that the students in the internal cohort could not adopt deep approaches and the associated qualitatively better thinking and learning outcomes. It merely means that, for whatever reason, they were not doing so.

In summary, this subsection has outlined the results of the quantitative explorations of students learning approaches, and how these have accorded with previous studies. It has established some broad patterns of learning approaches, and differences between learning approaches of internal and external student subgroups, which show areas of consistency and interesting inconsistency with previous findings.

1c: Students' descriptions of their learning approaches during interviews

This subsection addresses the third line of inquiry, with an individual level focus via student interviews and the differences between internal and external cohorts discussed.

Précis of results

The students' descriptions of their approaches to learning at interview showed the use of a range of different forms of memorising. Analysis of interview transcripts showed that descriptions of their learning by eight of these students were consistent with them having taken a surface approach to their learning in the topic, and two

appeared to describe a mixed approach to their study. A further five students described their learning in a way clearly consistent with a deep approach. The study behaviour of most of the interviewed external students as articulated at interview was coded as deep, while most of the internal students reported study behaviours characteristic of predominantly surface approaches.

Discussion

The different forms of memorising evident from students' descriptions of their approaches to learning at interview were consistent with those described by Meyer and Shanahan (2003). This was despite the fact that these indicators were not integrated into the interview protocol, as the interviews took place prior to 2003. In most cases the forms of memorising were allied in a coherent way to learning intention and focus. However, dissonant strategies of memorising before and after understanding were evident, in Tom's description of his mixed approach to learning.

> Just get it all down pat...keep it fresh in your mind so it's there so you can produce it on the test…
> I: What would make you go to the other book?
> S: If I didn't fully understand what they were trying to say. The different way they were saying it might've been better understood.

Jacinta's description of her learning approach fits well with Meyer and Shanahan's (2003, p. 7) description of "repetition as an aid to understanding".

> First of all it's to remember all the words … and then I will worry it until it makes sense...You had to know the words so you could think about them… Often it's rote learning.

This description also accords closely with the distinction between item and relational information (Dyne et al., 1994, pp. 380-382), and suggestions that deep learning in science does require an initial focus on detail, which may involve a form of rote-learning (Entwistle & Ramsden, 1983, p. 194; Ramsden, 1984, p. 157). The key here is that the attention to detail and rote-learning is a pathway to finding meaning. The other students showing a deep approach did not express this form of memorising, and their descriptions seemed to be more in line with the category of memorising after understanding. Students' forms of memorising, though, were not probed deeply in the interviews, so it is possible that some of the other students may have used a similar memorising strategy as Jacinta, but not expressed this at interview.

The account of her learning provided by Jacinta at interview also suggests that intrinsic motivation is not a necessary condition for deep learning approaches. Jacinta expressed a very strong intention to understand, and she focused on meaning, despite predominantly instrumental motivation. This finding parallels the proposition by Kember, Wong, and Leung (1999, pp. 326-327) that the extrinsically motivating influence of courses leading on to career paths can be a positive motivator that is consistent with intention to understand and a deep approach. Although Jacinta made no mention of a career, the topic was part of a unit that was prerequisite to other units that she really wanted to do because of very strong intrinsic interest in them. The SPQ has since been revised, partly in recognition of the positive and negative forms of extrinsic motivation in relation to deep and surface learning approaches (Biggs et al., 2001).

In summary, the results of student interviews provided complementary rich and detailed accounts of learning which complemented the general data obtained from the MSPQ. Students' accounts of their learning were particularly interesting in terms of forms of memorising and motivational aspects of learning.

1d: Relationship between quantitative (questionnaire) and qualitative (interview) assessments of learning approaches

The final line of inquiry within the learning approaches theme was the relationship between quantitative and qualitative data. This relationship is explored in this subsection, beginning with a brief outline of results which are then discussed more broadly.

Précis of results

The results from student interviews generally matched their responses to the MSPQ, except for cases where mixed approaches to learning were indicated by one or other of the data sources. In three out of the five cases of disagreement between interview and MSPQ responses, the students' description of their learning at interview resulted in a coding for one predominant approach, but these students had responded to the MSPQ in a way which suggested mixed approaches to learning.

Discussion

The agreement between the interview coding and MSPQ responses for eight of the thirteen interview participants is noteworthy, given that the two data collection

methods focused on slightly different aspects of learning approaches. The approach scales of the MSPQ are comprised of items pertaining to motive and strategy components, with the strategy items reflecting study behaviours directed by the intention to either understand or reproduce (Biggs, 1987, p. 11).

While the interview judgement criteria also considered motives and strategies, the additional aspect of learning focus was also emphasised, reflecting the importance of this issue in differentiating between learning approaches (Prosser & Trigwell, 1999, p. 91). Students were asked directly about their intentions, as learning intention has been argued to be "the most important aspect of the distinction between the two approaches". Also, it is common to the major idiographic and nomothetic accounts of deep and surface learning outlined in Chapter 2 (Kember, 1990, p. 343). An additional "strategy" indicator in the interview analyses focused on forms of memorising (Meyer & Shanahan, 2003). Given these differences between the interview and MSPQ instrument, the agreement between them indicates the robust nature of the deep and surface constructs.

Comparison of interview with MSPQ results also suggests that the MSPQ may be less powerful than interviews at discriminating between deep and surface approaches. This result is not altogether surprising, given the power of interviews in providing particularly deep and rich understanding of phenomena (Silverman, 2001, p. 32), and the likelihood of inflation of the number of apparent "mixed approaches" according to the MSPQ because of response sets. This result suggests that the MSPQ may have overestimated the incidence of mixed approaches in this study, reflecting the limitations of its discriminatory power.

In summary, in this subsection the extent of cross-corroboration between qualitative and quantitative data relating to learning approaches has been considered. This has shown general agreement between both aspects of the study, but also suggests that the MSPQ may be less powerful than interviews in discriminating between the predominant approaches to learning adopted by students.

Summary

The learning context showed characteristics typical of many first–year introductory science units, such as teacher–focused, information–transmission pedagogy, heavy

content load, and a high proportion of assessment by examination. The internal and external modes differed in many respects, as did internal and external students' perceptions of their learning situation. In general, many younger internal students found the topic boring and irrelevant, while many of the older, external cohort found the topic and its teaching interesting and relevant, which is consistent with previous research on engagement of mature–aged students with their studies.

Students' learning approaches were investigated against this background of context and students' perceptions. The reliability and validity of the MSPQ was commensurate with previous comparable studies, and the deep and surface constructs were uncorrelated scales, in common with much previous research. The "mixed" approaches to learning including neither deep nor surface approaches found in this study might have been inflated by response sets but are consistent with previous findings and theoretical considerations. The paucity of deep approaches in the younger internal cohort supports some criticism of the relevance of the 3P model to young non–traditional students in a mass tertiary system.

At the individual level, students' explanations of how they went about their learning enabled reliable judgements to be made about which learning approach they had predominantly adopted. Most external students expressed deep approaches and most of the internal students expressed more surface approaches. The students also described forms of memorising that were coherent with other indicators of learning approach and previous research.

Qualitative and quantitative methods of viewing learning approaches were essentially complementary, with interviews providing more discriminatory power in elucidating a predominant learning approach. Both the qualitative and quantitative results indicated that the external, older students showed more use of deep approaches and less of surface than their younger internal peers. This is entirely consistent with much previous research and with the general differences in their perceptions of the learning context.

Theme 2: Learning outcomes

This section discusses the results relating to students' learning outcomes, which were presented in Chapter 5. The lines of inquiry that guided this theme related to the

students' written responses to questions about the concept of meiosis including their fit to the SOLO model, the distribution of SOLO categories across the sample, students' explanations of meiosis during interview and the relationship between their verbal and written explanations of meiosis. Within these lines of inquiry were specific questions comparing outcomes of internally and externally–enrolled students. In this section, each of these lines of inquiry is discussed in turn.

2a: Students' written responses to meiosis questions

Qualitative differences in learning outcomes of the students were assessed by categorising their written responses to target meiosis questions in unit assessment tasks, using the most recent version of the SOLO model. A précis of the results of this process is provided, followed by a discussion of the findings in relation to previous relevant literature.

Précis of results

The students' written responses to the meiosis questions fell into three broad groups, which were consistent with the two-learning-cycle per mode SOLO model. The first group, where meiosis was conflated with other concepts, was consistent with the first cycle of the concrete-symbolic mode of SOLO. The second group of responses fit with the second cycle of the concrete-symbolic mode, where responses described meiosis as a distinct concept and partially described the process. The third group of responses was consistent with the first cycle of the formal mode, and dealt with the more abstract role of homologous pairs – a crucial component of meiosis. Within all of these cycles, categories of response were identified at the unistructural, multistructural and relational levels. This represented increasing structural complexity.

This categorisation was reliable across three judges and its validity was supported by strong correlations with independently assigned marks for the responses. Once established, the final SOLO categorisation of responses was relatively reliable, correlated strongly with marks and made coding of most subsequent responses relatively quick and easy.

Discussion

The fit of the categories of response to the two-learning-cycle per mode SOLO model (Pegg, 2003; Pegg & Davey, 1998) concurs with the only other directly comparable investigation (Panizzon, 1999, 2003) in supporting the validity of the model. The results support the conclusion of Hazel, Prosser, and Trigwell (2002, p. 741) that SOLO is a useful and "robust" tool in assessing examination responses, although their comment was based on using the less complex single-cycle per mode version of SOLO. The analysis itself, however, was a time–consuming and difficult task, which highlights limitations of the utility of SOLO as an assessment tool in similar contexts. Initial iterations of categorising responses were extremely labile, and establishing the categories benefited greatly from the multiple perspectives of the co-researchers involved in this part of the study.

The initial difficulties in establishing the categories resulted from several factors. One issue was the complexity of the concept and the amount of jargon required to communicate it. This jargon was confusing to the students in this study, as well as to students described in previous research (e.g., Smith, 1991). This was evident in quite a lot of "noise" and internal inconsistency within and between the elements in some of the responses.

Another contributing factor was the different language that students used to describe the same process. This led to two parallel but structurally equivalent strands within Categories 7-11; responses using stage names and/or mitosis to explain the process of meiosis, and responses using phase names. More variation between responses resulted from the fact that some students used diagrams to support their answer, and some did not. A related problem was that some responses comprised the same, much abbreviated, summary diagram that was apparently reproduced from the textbook, with no additional annotation or explanation. This final point illustrates the disadvantage of measuring learning outcome using examination questions, which may promote regurgitation of rote-learned and poorly understood material (Thomas & Bain, 1984).

The process of analysing the responses in this study was of interest in light of the statement that "while the SOLO taxonomy can be used to describe differences in structure generically, it does not describe differences in meaning at all" (Prosser &

Trigwell, 1999, p. 120). This may have been true for earlier versions of SOLO, but the results of this study suggest that it does not apply so absolutely to the more complex two-cycles per mode version. First, it is the degree of abstraction of the content that determines the SOLO modes, and the degree of abstraction related directly to the presence or absence of differentially abstract concepts addressed in the responses, that is, to aspects of the meaning.

In addition, it was found that structure and meaning were linked in applying SOLO model, just as they have been described by Marton and Booth (1997, p. 87) in the context of phenomenography. For poor SOLO responses (uni- or multistructural), within a given cycle, there was little structure without meaning, (and little meaning without structure). Misconceptions, areas of confusion and misuse of terms weakened the consistency, coherence and therefore the structure of some responses to a greater or lesser extent, depending on the number and magnitude of the areas of confusion. Relational responses derived their structure partly from the combination of elements they contained, that is, the meaning that they contained. Conversely, much of their meaning was derived from the way they were structured, so that relational responses had a more sophisticated meaning than those at the multistructural level. This relates to the issue of coherence. As discussed by Biggs and Collis (1982, p. 215), relational responses are an integrated, "coherent whole". Pegg (2003, p. 243) also emphasised the importance of coherence in relational responses: "the whole has become a coherent structure. No inconsistency is present within the known system."

A similar relationship between meaning and structure has been highlighted from a cognitive science perspective:

> Our complicated ideas are built out of simpler ones, and the meaning of the whole is determined by the meanings of the parts and the meanings of the relations that connect them. (Pinker, 1999, p. 564)

Although there did seem to be a relationship between structure and meaning in many of the responses, a number of responses in the first cycle of the concrete–symbolic mode received the same SOLO code despite quite different meanings. This was not so evident in the second cycle, concrete–symbolic mode or the formal mode, probably because of the tight interrelationships between the concepts within meiosis. This relationship between structure and content/context was addressed by Pegg

(2003, p. 241), who suggested that SOLO provided a "balanced theoretical perspective that has relevance to all individuals but which is able to be considered relevant to specific topic areas."

In summary, this subsection has outlined the categories of written responses to meiosis questions and their concordance with the two-learning-cycle version of the SOLO model. This concurs with the only directly comparable previous study. Difficulties in categorising responses resulted from use of different language, and the results highlighted the inter-play between structure and meaning in the SOLO model.

2b: Patterns of distribution of SOLO categories

The distribution of SOLO categories of students' written responses to meiosis questions was the second line of inquiry pertaining to the learning outcomes. This subsubsection summarises broad patterns of the distribution across modes and levels, and across student subgroups. These general findings are then compared to previous relevant research.

Précis of results

Most of the responses were within the second cycle concrete–symbolic mode and, more specifically, the M_2 level of response. No differences in patterns of response were detected between internal or external students, nor were there any differences in response associated with student age or gender.

Discussion

The distribution of responses across the different SOLO modes and levels in this study is broadly consistent with the findings from a comparable study of first–year science students' understandings of diffusion at the same institution (Panizzon, 1999, pp. 198-199; 2003, p. 1437). The results from both studies are shown in Table 7.1.

Table 7.1: Percentage of responses in SOLO categories from two studies of students' learning in first–year biology

Study	Concrete–symbolic mode: %						Formal mode: %			
	U_1	M_1	R_1	U_2	M_2	R_2	U_1	M_1	R_1	U_2
Current study: meiosis	0.5	5	2	9	41	9	12	9	2	0
Panizzon 2003: diffusion	5	4	14	3	35	10	3	1	1	3

As shown in Table 7.1, in both studies the most frequently represented level is M_2, the concrete–symbolic mode contained the vast majority of responses, and relatively few responses were in the formal mode. Some differences, though are apparent between the findings of both studies. In this study, fewer students responded in the first cycle concrete–symbolic mode, and about four times as many students as those in the Panizzon (2003) study responded in the formal mode. This may relate to the fact that an actual assessment question was used as a measure of learning outcome in the current study, which may have provided students with more of an incentive to answer as well as they could.

The low proportion of students responding in the formal mode in this study, relative to the concrete–symbolic mode, appears to reflect the findings of previous research on students' understanding of meiosis. As outlined in Chapter 5, in this study the formal mode was indicated by students' responses referring to homologous pairs and the crucial role they play in meiosis. A study of students sitting the University of Cambridge A–level biology practical paper (Brown, 1990) found that only 13.5 % of the total sample of 614 students could demonstrate the structure and arrangement of homologues in meiosis. Another study found that only 22% of a sample of 54 undergraduates could complete a task demonstrating the chromosomal basis of independent assortment in meiosis, a task depending on an understanding of the role of homologues (Thomas, 1988, cited in Brown, 1990, p. 185). The small number of students responding at the formal mode in this study appears not to be atypical of introductory biology students studying meiosis.

This finding raises the question of whether the large proportion of students responding at the concrete–symbolic mode, in this and other studies, have responded in a way that is consistent with expectations of university standards. It has been argued by Biggs and Collis (1991, p. 61-67), and Collis and Biggs (1991, p. 188-191) that the formal mode is the target mode for undergraduate university study, as students require the theoretical knowledge associated with the formal mode to understand abstract academic disciplines. The students in this study and sitting the Cambridge A–level paper (Brown, 1990) certainly have not reached this target in the context of meiosis.

Is, then, the formal mode really an achievable target for many first–year students in introductory units who are exposed to such a broad range of concepts? It has been suggested by Boulton-Lewis (1998a, p. 206) that in new disciplinary areas, students may perform at the concrete–symbolic mode, acquiring only declarative and procedural knowledge. This certainly appears to have been the expectation of one of the lecturers involved in this study. His comments during lectures outlined in Chapter 4 implied quite strongly that he did not expect the students to understand fully the process of meiosis, but that he was hoping for the students to remember a few key points about meiosis. In terms of the SOLO categorisation established in this study he was expecting his students to respond to the material at the concrete–symbolic mode. Whether this expectation may have limited the performance of some students is not clear, but the lecturer in the subsequent year did not communicate this emphasis to the students and there was no significant difference in outcomes between the years. It does seem on the basis of these results, though, that breadth of content in a broad service–level introductory unit may contribute to limited understandings of the more theoretical forms of knowledge in the formal mode.

The lack of significant associations between SOLO level attained and enrolment cohort of the students (older external or younger internal) is in accord with Russell's (2006) widely reported "no significant difference phenomenon", which suggests that learning outcomes generally do not differ significantly between distance and classroom–based instruction. A meta-analysis of over two hundred comparative studies by Bernard et al., (2004), however, has disputed Russell's claim, finding extreme variability in the relative effectiveness of distance versus classroom–based instruction. In asynchronous distance compared with on–campus contexts, though, Bernard et al. (2004, pp. 408-409) found that distance students fared better in both attitudes and outcomes. The fact that the present study found better attitudes (in the sense of learning approaches) but no difference in outcomes of mature–aged, external students is of note. It is perhaps unsurprising, considering the distribution of responses with such a peak at M_2, but also of potential concern, given that many studies (reviewed by Krause et al., 2005; Richardson, 1998) suggested generally that mature–aged students tend to have better learning outcomes than their younger peers.

The non-relationship between outcome and age in this study is consistent with Panizzon's finding of no difference between Yr 11/12 and first–year biology

students' understanding of diffusion after instruction. The formal mode is considered to become available to individuals by about age 16 (Biggs & Collis, 1991). This suggests that given enough time and the intention to understand, most of the students in this study could have responded to the meiosis question at the formal mode. However, the paucity of formal responses in the students in this study may relate to many factors in addition to learning approach. These include the context–dependent nature of students' responses, content overload, the issue of mismatch between the goals and values of the learners and the institution raised by Haggis (2003) as well as the developmental nature of learning as reflected in the SOLO hierarchy, where learning proceeds from lower to higher modes.

In summary, the pattern of distribution of SOLO categories described in this subsection shows a concentration of responses in the concrete–symbolic mode. This pattern accords with findings from the only other directly comparable study. The paucity of formal responses has implications for introductory science teaching and learning. The lack of significant difference in outcomes between internal and external cohorts is an issue of concern, though consistent with some previous literature.

2c: Students' explanations of meiosis during interviews

To complement the data derived from students' written responses, students were interviewed about their understanding of meiosis, and their explanations coded using the SOLO model. In this subsection a précis of results is provided, and these results are then discussed in terms of the findings of other studies into students' understandings of meiosis.

Précis of results

Interviews with sixteen students about their understanding of meiosis again resulted in most students responding at the second cycle, concrete–symbolic mode. There were some differences between internal and external students and/or younger and older students apparent in the interview data. Three of the five external students, who were also old relative to the other students, responded in the formal mode. The responses of the 11 internal students were evenly distributed between the Low and High SOLO groups; however, only two responded in the formal mode.

The students' explanations of meiosis during interviews confirmed the indication from the written responses of widespread problems with understanding of meiosis. Many of the interviewed students demonstrated misconceptions and areas of confusion about meiosis, particularly relating to homologues, terminology such as chromosomes and chromatids, and the hierarchy of biological structures. Only two students that were interviewed could explain meiosis at a level comparable to the first–year textbook.

Discussion

The conceptual difficulties revealed in interviews with students in this study, are consistent with past research into students' understandings of this topic. In particular, the specific areas of confusion and misconceptions about the distinctions between homologues, chromosomes and chromatids are consistent with previous findings. That the vast majority of students did not express a relational understanding of meiosis even at the concrete–symbolic level no doubt reflects these areas of confusion which surround many of the elements of meiosis, each of which is itself conceptually complex. These results indicated that many of the students did not comprehend some of the concepts and propositions relating to meiosis to the level that has been expected of Year 10 students (Hackling & Treagust, 1982, p. 80).

The confusion about the specifics of meiosis shown by students in this study accords with a number of detailed interview–based studies at the high school level (e.g., Hackling & Treagust, 1982; Longden, 1982; Stewart & Dale, 1989). These studies identified similar problems relating to misunderstandings of structures such as chromosomes and chromatids. The suggestion of some of the students in this study that replicated chromosomes were formed by the joining of two independent chromatids was also found in previous studies at the tertiary level (Kindfield, 1991, p. 194; Smith, 1991, p. 30). The lack of clarity about the distinctive nature of homologous chromosomes shown by students in this study is also supported by previous research by Kindfield (1991), who identified a series of misconceptions relating to the origin of and differences between homologous chromosomes and replicated 2–DNA molecule chromosomes.

The apparent prevalence of these areas of confusion is unsurprising, given the blurry definition of the word chromosome (Fisher et al., 1986, p. 279) which can mean

either the replicated two–DNA molecule structure, or a single–DNA molecule structure (Kindfield, 1991, p. 194). In addition, the jargon that is associated with these concepts and other related structures contributes to the problem. For example, Smith (1991, p. 30) cited confused definitions of terms such as homologous chromosomes and sister chromatids, centromere and centriole, and chromosome and chromatid.

It is likely that the students' variable understandings after instruction in meiosis during this study may be at least partially related to prior knowledge of meiosis or its subordinate concepts from secondary school. In the New South Wales junior secondary science curriculum (Years 7-10), the concepts of DNA, genes and chromosomes are core material (New South Wales Board of Studies, 1998), but the concept of meiosis itself is optional. Meiosis was not covered in any of the three popular Australian junior secondary science texts examined (Jenkins, Sweeny, Relph, & DeLacey, 1990; Parkes, 1993; Wilson & Bauer, 1991), so it is likely that students would not have covered meiosis prior to Year 11.

The senior secondary New South Wales biology course (Years 11 & 12) lists meiosis as a core item, and the concept is described in all the Australian senior secondary texts and study guides examined (Australian Academy of Science, 1973, 1992; Fung, 1993; King & Sullivan, 1996; Mudie & Brotherton, 1989, 1992; Snyder, Kennedy, & Aubusson, 1990). Because senior secondary biology was not a prerequisite for the introductory biology units in this study, meiosis was probably familiar to those having studied biology in Years 11 or 12, but unfamiliar to commencing students who had not done any biology since Year 10. This would also have been the case for most of the mature–aged students whose formal science education was several years prior to enrolling.

Although the vast majority of students in this study had encountered meiosis in the previous semester's biology unit, it is likely that residual effects of variable prior understanding were still in existence. Deep approaches and better outcomes in science are more likely when students have good prior understanding (Biggs, 1970a; Hazel et al., 2002; Hegarty-Hazel & Prosser, 1991b). However, it was clear from interviews that a number of the students who had studied meiosis, and believed that they were on top of it, did not demonstrate high–quality learning outcomes. For some

students, their inaccurate assessment of their prior understanding appeared to lead to a degree of inappropriate complacency, in a similar way as that described by Baird and Mitchell (1987, p. 9). This perhaps worked against students adopting deep approaches and achieving better learning outcomes.

It is interesting to examine the students' misunderstandings of the nature of chromosomes and their replication in the light of the treatment of meiosis in secondary textbooks. In senior science syllabuses, meiosis is usually introduced in the specific context of chromosomal and organismal reproduction, though occasionally (King & Sullivan, 1996) within the context of inheritance. Although several of the senior secondary texts relate chromosomes to DNA and/or genes in the introductory material, none of the texts explicitly invoke DNA synthesis and replication as the explanation for chromosome replication – the tight conceptual relationship between DNA and reproducing chromosomes is not made as explicit as it could be. In these texts the mechanism of chromosome replication remains mysterious, for example, "each chromosome is now seen to contain two threads" (King & Sullivan, 1996, p. 134). Only one text (Australian Academy of Science, 1992) subsequently relates meiosis back to DNA and DNA replication. Similarly, only three of the texts (Australian Academy of Science, 1992; Mudie & Brotherton, 1989, 1992) explain the origin of and relationship between homologous chromosome pairs.

This situation accords with a study of American secondary science texts as possible sources of misconceptions about genetics (Cho, Kahle, & Nordland, 1985). These authors concluded that none of the three major texts explained the mechanism of chromosome replication or the origin of homologous chromosomes. It seems, then, that chromosome replication and homologues are a blurry area in the treatment of meiosis in American and Australian secondary texts, and in the minds of students.

At least in the Australian case, this confusion may relate to the fact that meiosis is often explained in the context of cellular and organismal reproduction (with good reason), while its constituent parts (DNA, genes, chromosomes) are detailed in a separate genetics section (with equally good reason). Students may well perceive these as separate topics without making the necessary links between them, which

might preclude a relational understanding of the concept of meiosis which crosses these sub-disciplinary areas.

In summary, in this subsection the results from students' verbal explanations of meiosis are outlined, including misunderstandings and areas of confusion. Previous studies involving high school and university students indicate that the difficulties in understanding meiosis expressed by the students in this study are not uncommon. Some possible contributing factors to these widespread difficulties relate to the complexity and abstract nature of the process, confusing terminology, and possibly the treatment of meiosis and related concepts at school.

2d: Relationship between written and interview explanations of meiosis

The final line of inquiry in the learning outcomes theme of this study related to the relationship between written and interview data. This relationship is summarised in this subsection, and then discussed in the context of theoretical expectations.

Précis of results

The SOLO codes of students' descriptions of meiosis at interview were compared with their responses to practical test and examination responses. This showed some students receiving consistent codes across the different outcome measures, while others showed considerable variability. Only three students responded at the same SOLO level in the examination question and the interview. The remainder of the students was evenly split, with six students performing better in the examination than the interview, and six worse. Students' responses, then, were generally not particularly stable between interviews and their written responses to earlier practical test questions or later examination questions.

Discussion

The lack of stability of students' responses to meiosis questions across the different contexts of practical tests, interviews and examinations is consistent with the finding of Marton & Säljö (1976, as described by Biggs, 1980, pp. 104-105) and the conceptual basis of the SOLO model. Marton and Säljö had found different levels of response by undergraduates to a particular item, and these levels were, according to Biggs (1980, p. 104), entirely consistent with the early SOLO categories. These authors also found that responses to the same item varied considerably on retesting,

which Biggs (1980, p. 104) equated to changes of two to three SOLO levels (according to the early version of the model). Instability of responses, that is, horizontal décalage, is entirely consistent with the theoretical basis of the SOLO model which accommodates different performances of individuals across different contexts.

In summary, this subsection considers the issues of stability and instability of responses to questions about meiosis, which have been asked using different methods and at different times. The instability of responses found in this study is compared to other studies and is consistent with the assumptions of the SOLO model.

Summary

The analysis of students' written responses to the meiosis question was reconcilable with the SOLO model. Some difficulties were associated with using the two-learning-cycle version of the model in the study context, together with advantages pertaining to the relationship between meaning and structure in responses. The results obtained were consistent in many respects with the only previous study of in a tertiary biology context using the new version of the SOLO model, especially the majority of responses at the concrete–symbolic mode.

The lack of association between SOLO level and age or enrolment is of interest, given some theoretical grounds for expecting better outcomes from mature–aged students. The students' areas of confusion with meiosis which were revealed by interviews reflected well–documented difficulties in understanding meiosis, with some possible links to treatments of meiosis and related concepts in secondary science texts. Finally, instability of responses to questions in different contexts in this and other studies is both assumed and accommodated by the SOLO model.

Theme 3: Relationship between learning approaches and outcomes

This section discusses results pertaining to the relationship between students' learning approaches and outcomes, which were presented in Chapter 6. The lines of inquiry guiding this theme investigated the relationship between students' responses to the MSPQ and the SOLO level of their written responses to meiosis questions, including comparison of internally and externally enrolled cohorts. The relationship

between students' learning approaches as expressed at interview and their verbal and written explanations of meiosis was also examined. Each of these lines of inquiry is addressed in turn in this section.

3a: Relationship between MSPQ responses and learning outcomes: all students

This first line of inquiry aimed to explore the relationships between MSPQ responses and learning outcomes across the total sample. The results are first briefly summarised, and then discussed in terms of other relevant research.

Précis of results

Quantitative analyses consistently showed a weak relationship between learning approach and outcome, with better outcomes tending to be associated with predominantly deep learning approaches, and poorer outcomes with surface or mixed approaches. In terms of banded learning approach abilities, better learning outcomes were more frequent only in the group of students reporting a predominantly deep approach. Poorer outcomes were relatively more frequent in groups of students with predominantly surface approaches to learning. In the group of students who adopted both approaches to a relatively similar extent, the frequency of better learning outcomes was roughly equivalent to the group adopting surface approaches.

Finer scale examination of learning approaches by cluster analyses showed that the two clusters with the highest relative frequency of poor responses were those showing either mixed approaches or slightly more surface than deep approaches. These clusters comprised the majority of students (about 60%), and poor outcomes were more frequent in these clusters than in the strongly surface cluster.

Discussion

The association found in this study between deep approaches and better–quality outcomes is in accordance with much previous research. In his original quantitative study using the SPQ and SOLO assessment of learning tasks in a natural setting, Biggs found a weak relationship between deep orientations and relational or higher SOLO responses (which translates to a response level of R_2 or above according to the model used in this study). Biggs' (1979) findings were consistent with the results of the seminal interview studies using artificial reading tasks (Marton & Säljö, 1976a). Much subsequent research (reviewed by Prosser & Trigwell, 1999) has shown

similar relationships between deep approaches and better outcomes in natural settings. Moreover, the relationship between deep approaches and better SOLO levels has been found in other studies on Australian first or second year tertiary students using the early versions of SOLO (e.g., Hazel et al., 2002; Prosser et al., 1996; Tang, 1998; Trigwell & Prosser, 1991; Watkins, 1983).

The relationship between surface approaches and poorer SOLO levels in the examination question is also consistent with the hypothesised relationship between approach and outcome variables. It was predicted by Biggs (1979) that students adopting surface approaches (orientations according to the definitions used in this study) would be more likely to respond at a multistructural level (in terms of the model in this study this is equivalent to M_2 or less). Although he found no main effect between SOLO level and the utilising (surface) scale, the utilising scale tended to lead to retention of details rather than more complex responses. This finding is also consistent with many previous quantitative studies into the association between surface approach and outcome variables (e.g., Crawford et al., 1998a; Hazel et al., 2002; Hegarty-Hazel & Prosser, 1991a). This relationship is widely accepted in reviews of these aspects of higher education teaching and learning (e.g., Prosser & Trigwell, 1999; Ramsden, 1992).

The results of this study also highlight some differences in relationships between approach and outcome, related to the measure of outcome used. Surface approaches correlated negatively with SOLO levels but not with marks obtained for the examination question. This suggests some limitations of using marks as measures of learning outcome, which in the present context have not reflected the qualitatively poorer responses associated with surface approaches that were identified by the SOLO categories. Similar mismatch between the findings of qualitative and quantitative measures of learning outcome has been reviewed by Trigwell and Prosser (1991). Their study based on first–year nursing students at the course level found that deep approaches related positively to SOLO measures of outcome but not marks, while surface approaches correlated with neither SOLO levels nor assessment marks (Trigwell & Prosser, 1991, pp. 270-271). The slightly different but complementary findings of this study support the doubt cast by Trigwell and Prosser (1991) on the validity of using quantitative measures of learning outcome such as marks.

The poor outcomes associated with mixed or essentially no approaches to learning also support evidence from previous studies (Entwistle et al., 1991; Meyer et al., 1990; Prosser et al., 1996). This finding has also been established more specifically using SOLO as a measure of first–year biology students' understanding of photosynthesis (Hazel et al., 2002).

In summary, this subsection has described consistent but statistically weak support for the hypothesised correlation between approach and qualitative (SOLO) measures of outcome. This association was not found for quantitative outcome measures (marks), and both of these findings are in line with many previous nomothetic investigations into the approach/outcome nexus.

3b: Relationship between MSPQ responses and learning outcomes: comparison of internal and external students

In this line of inquiry the relationship between approaches and outcomes was explored separately for internal and external students. A précis of results is provided in this subsection, followed by a discussion of their significance in terms of the internal and external cohorts.

Précis of results

It was noteworthy in this study that the relationship between deep approaches and better examination question outcomes that was found for the whole cohort was weak, and almost entirely due to results obtained from the external, older cohort. In that group, there was a strong correlation between deeper approaches and better outcome, with moderately large effect sizes. For internal students, there was no relationship between deep approaches and better examination question outcomes. This study, then, only partially supports the hypothesised relationship between deep approaches and better SOLO outcomes of learning. This was true only for the external, mature–aged cohort.

The converse situation was found for the relationship between surface approaches and examination question outcomes. This was found only for the younger, internal cohort, where there was a weak correlation between surface approach and SOLO measures of examination question outcomes, together with a significantly higher surface approach mean in the Low SOLO group. However, for internal students there

was no relationship between surface (or deep) approaches and outcomes for the meiosis question in the practical test.

A similar pattern was evident when the analytic perspective was shifted to groups of students with similar patterns of deep and surface approaches. For internal students, relatively more frequent High SOLO responses occurred in the cluster with about average deep combined with very low surface means. Low SOLO responses were more frequent in the clusters with somewhat surface and mixed approaches, than in the strongly surface cluster. For external students, poor responses occurred relatively more often in a cluster with mixed deep and surface approaches, and better responses in a cluster with very high deep and low surface approaches. The cluster with the poorest outcomes was a group of students adopting essentially no approaches to learning, which was about 20% of the cohort.

A synthesis of the findings of the three results chapters highlights an interesting aspect of the learning and performance of internal versus external students. In Chapter 4 it was found that external students reported more use of deep approach and less use of surface approach than internal students. In Chapter 5 it was found that there was no difference in learning outcomes between internal and external students, with response frequencies of both subgroups showing a significant peak at M_2. In Chapter 6 it was found that deep approaches were positively related to higher SOLO levels for external students, while more surface approaches were negatively related to higher SOLO levels for internal students.

This combination of results leads to the interesting paradox that although external students had deeper approaches than internal students, and that although deep approaches in external students were also positively correlated with better learning outcomes as measured by written responses to the examination question, external students in fact performed no better overall in the examination question than internal students.

Discussion

The non-relationship between deeper approaches and better learning outcome variables in the younger, internal cohort contrasts with much of the previous research cited above which supports a relationship between deep approaches and better

learning outcomes. As noted in Chapter 2, most of these previous studies took place in large metropolitan universities with a different student population to that in this study.

One parsimonious explanation for the non-relationship between deep approach and better outcome for the younger, internal cohort in this study is that too few of these students approached their learning sufficiently deeply for deep approaches to be reflected in better–quality outcomes. The fact that no clusters of internal students showed high deep and low surface cluster means supports this argument. As outlined in Chapter 3, the student population at UNE comprises a large proportion of students who are in many senses marginal to the traditional world of tertiary education. The perceptions of such students to their learning situation, and concomitantly their learning approaches, are therefore likely to be different to more traditional student populations. The contrast between the findings of this and previous studies might, therefore, reflect the contrast between the characteristics of the student populations on which they were based. This, if the case, would support the contention by Haggis (2003, p. 102) that the approaches to learning/learning outcomes model may not be particularly helpful in making the tertiary system "a genuinely accessible form of education for 50% of 18 year olds."

Other explanations for the contrast between the findings of this and previous studies are also possible. For instance, it could be that the learning context in this study was less supportive of a deep approach than other comparable studies. The problem with this explanation is that the relationship between deep approaches and learning outcomes was evident in the older external cohort, a result which is more consistent with the findings of the previous studies outlined above. These students experienced a learning context that comprised the same content, comparable assessment (exactly the same examination), traditional lecture and practical format in a residential school, much less weekly feedback on their understanding and less social engagement. These aspects of the context are theoretically no more supportive of a deep approach than the younger internal context. Nonetheless, the perceptions of these students to their learning situation differed markedly from their younger, internal peers, in a way that relates coherently to their deeper learning approaches.

Another potential explanation for the lack of relationship between deeper approaches and better outcomes for younger, internal students only, relates to their prior knowledge. These students could have had better prior knowledge from their more recent school experiences, which may have lead to better learning outcomes despite surface approaches being adopted (for discussion on the relationship between prior understanding and outcomes see Prosser & Trigwell, 1999). This seemed to be the case in two of the interviewed students (Charlie and Ruth). The vast majority of internal and external students, however, had received instruction on meiosis in a genetics topic in the previous semester, that would have reduced this potential effect. Prior knowledge in science is also associated with deep approaches according to the 3P model and much previous research (e.g., Biggs, 1970a; Entwistle & Ramsden, 1983; Hazel et al., 2002; Hegarty-Hazel & Prosser, 1991c), but deep approaches were not evident in the internal cohort. So even if the better performance of the younger, internal students related to prior knowledge, the theoretical relationship between prior knowledge and approaches was not apparent in this cohort.

The relationship within the younger internal cohort between surface approaches and poorer SOLO levels in the examination question, is consistent with previous studies cited above, and the hypothesised relationship between approach and outcome variables. By contrast, though, the fact that surface approaches were not associated with poorer quality outcomes in the practical test question is inconsistent with the theoretically predicted relationship. It seems that a surface approach did not hinder students' performance in the practical test and that cramming for reproduction may have been rewarded in this assessment context. Students can succeed in test questions by recalling poorly understood information from short-term memory (Svensson 1984 cited in Trigwell & Prosser, 1991. p. 265). This may have been easier to achieve for the practical test question which was much closer to the time of instruction than the examination question, and part of an assessment covering much less content than the examination. While it is perhaps unlikely that the complexity of responses at R_2 and above could be achieved solely by the "cram and dump" method, surface approaches combined with reasonable prior knowledge could explain this result.

The relationship between surface approaches and poorer outcome variables for the internal cohort was less robust than the relationship between deep approaches and

better outcomes for external students, with only a small correlation and a small to moderate effect sizes. This finding is also consistent with other studies that have found that the correlation between surface approaches and outcomes is less than the correlations between deep approaches and better outcomes (e.g., Hegarty-Hazel & Prosser, 1991a, p. 309). Some other studies have failed to find an association between quantitative measures of surface approaches and poor quality outcomes (e.g., Trigwell & Prosser, 1991). These findings may reflect the limitations of the surface scale of the SPQ, which was less reliable than the deep scale in this study. This has consistently been the case in previous studies (for a summary see Watkins, 1998, p. 132).

The finding that the surface approach variable was not associated with the poorer outcome variable in external students contrasts with a large study of distance students at the Open University. This previous study had found a strong negative association between reproducing orientation to learning and course grades (Richardson et al., 1999). The non-relationship between surface approach and poorer outcome for the older, external cohort in this study may be because too few of these students adopted a surface approach to learning for this to be reflected in poorer outcomes. This possibility is supported by the fact that there were no clusters of external students reporting strongly surface approaches. This is a likely reflection of the characteristics of the external sample, who were mature–aged and whose perceptions of their learning situation were quite different to the younger, internal group.

The final point of discussion in this subsection relates to an aspect of findings of quantitative data synthesised from the three themes of learning approach, outcome, and relationship between them. If older, external students had deeper approaches, and if the external students' deeper approaches were positively associated with better examination question responses, why were their responses to the target question on the examination no better overall than the internal students? Why was there no significant difference in outcome? A possible reason for this result is that the association between deep approach and better outcomes was moderate, and not strong enough for differences in outcome to be detected, given the very high frequency of responses overall at M_2.

In summary, this subsection has highlighted the quite marked differences in the relationship between approach and outcome for internal and external students. In particular, the non-relationship between deep approach and better outcomes for the younger, internal cohort is in interesting contrast to many previous studies. The findings in this subsection may relate to the characteristics of the student cohorts in this study, as is suggested in the light of some previous relevant research.

3c: Relationship between learning approaches and outcomes expressed at interview

The final line of inquiry explored the information obtained from student interviews. It covered the approaches students adopted, their understanding of meiosis, and compared these findings with quantitative aspects of the study. The first part of this subsection summarises the major findings, which are then discussed in terms of other relevant idiographic research.

Précis of results

At the individual level, interviews with students strongly supported the hypothesised relationship between approach and outcome. Most students whose interviews indicated a surface approach generally could explain meiosis at a level less than or equal to M_2, and the two exceptions reported strong prior understanding of meiosis. Conversely, most students who described their learning in a way consistent with a deep approach at interview explained meiosis at a response level equal to or above R_2.

In addition, students reporting surface approaches to their learning (mostly internal students, according to MSPQ responses) generally performed better in later written responses to test questions than in their explanations of meiosis at interview. This finding contrasts with the students who reported a deep approach to their learning (mostly external students, according to MSPQ responses), who performed worse in written responses to test questions than in verbal explanations of meiosis.

Discussion

The findings from individual student interviews in this study, which strongly supported the hypothesised relationship between learning approaches and SOLO levels, are in close accord with the original work of Marton and Säljö (1976a) and subsequent qualitative studies. For example, van Rossum and Schenk (1984, p. 80)

found that a surface approach to learning limited the learning outcome to the multistructural level, and Watkins (1983, p. 57) found that 23 out of 29 students using a surface approach achieved a multistructural or lower SOLO outcome (i.e., M_2 or less in terms of the model being used in this study).

Although based on only 16 interviews, it is of note that students who adopted a deep approach performed worse in the examination question than their interview (and the converse for surface approaches). This is in direct contradiction to the better retention which is theoretically expected from the more meaningful understanding associated with deeper approaches (Ramsden, 1992, p. 60), and which has been shown in a previous study of meiosis (Cavallo, 1992). This result raises the possibility that the mature–aged external students may be disadvantaged relative to more recent school–leavers by standard high–stakes end-of-semester examinations, as has been suggested by Sutherland (1998, p. 199). This would support the view of one of the unit lecturers that "internals are better at passing exams and externals are better at learning", and reflects possible limitations of using examination responses as a measure of students' understanding.

In summary, at the individual level, this line of inquiry demonstrated strong support the hypothesised relationship between approach and SOLO level of outcome, as has been found in previous studies. The poorer examination relative to interview performance demonstrated by students adopting a deep approach casts some doubt on examinations as a measure of meaningful understanding, but this interpretation is tentative as findings were based on a limited student sample.

Summary

The weak relationship found in this study between deep approaches and better learning outcomes, and surface approaches and poorer learning outcomes, is consistent with the direction of previous nomothetic research. This finding for the whole sample, though, was quite different when internal and external cohorts were viewed separately.

The theoretically predicted relationship between deep approaches and better outcomes was found in the older external cohort. This was despite aspects of their learning context which would theoretically favour surface approaches, but was in

accord with the students' greater age and their perceptions of their learning situation. The non-relationship between deep approaches and better outcome variables for the internal cohort in this study contrasts with much previous research, and this may reflect the characteristics of the diverse student population in the study context. If so, this adds weight to recent criticism of the extent to which the learning approaches/outcomes theory enhances accessibility of tertiary education for non-traditional school leavers.

The predicted relationship between surface approaches and poorer outcomes was found only in the internal, younger cohort for the examination question only. The lack of this relationship in older external students contrasts with some previous research on learning orientations, but probably reflects the low incidence of surface approach in this cohort. The poor outcomes evident in groups of students with mixed or essentially no approaches to learning, is in accord with previous research.

The fact that the older, external students had no better outcomes than the younger cohort despite their theoretically more desirable learning approaches may be a statistical artefact but also raises the possibility of better learning that went unrecognised by the assessment regime. Finally, interviews with students strongly supported the hypothesised relationship between surface approaches and outcomes at M_2 or below, and deep approaches with responses at or better than R_2, as predicted in seminal studies and found in relation to previous versions of the SOLO model.

This chapter has presented a synthesis of the results of the three themes of this study together with relevant literature into student learning in higher education. The following chapter presents some conclusions emerging from this synthesis, and outlines some limitations to the study and its implications for practice, theory and future research.