Chapter 4

Results: Learning Approaches

Introduction

The research methodology outlined in the previous chapter focused on the three study themes of learning approach, learning outcome, and the relationships between these two aspects of student learning. This chapter presents the results pertaining to research theme 1: students' approaches to learning, and is explicitly organised in terms of the four lines of inquiry that were posed for this theme in Chapter 2, which are:

1a. What are the characteristics of the particular teaching and learning context which might influence students' approaches to learning?

1b. What do students' responses to a topic – specific learning approaches questionnaire (MSPQ) show about their approaches to learning in a particular topic?

1c. How do students describe in interviews the learning approaches they adopted in a particular topic?

1d. What is the relationship (if any) between the assessment of learning approaches using quantitative (questionnaire) and qualitative (interview) methods?

This chapter outlines the results pertaining to these questions, starting with observations and interviews relating to the learning context. Results of the nomothetic investigation of students' learning approaches based on their responses to the MSPQ are then outlined, followed by the idiographic exploration of students' approaches to learning using interviews. The relationship between the results of these two complementary perspectives and methods is then examined.

1a: Characteristics of teaching and learning context

The description of the teaching and learning context at the heart of this study was guided by two research questions:

1a.i: What are the institutional and teaching characteristics of the learning environment?

1a.ii: What are the students' perceptions of the learning context?

The results below are derived from interviews with staff and students, observations of all the practical and lecture sessions in the topic for both internal and external students, and examination of unit documentation. In quotations from interviews, interviewer questions are preceded by "I:", while students' responses are indicated by "S:"

1a.i: Institutional and teaching characteristics

The characteristics of the teaching and learning context at the focus of this study are described below. The syllabus and content, lectures and practical sessions, and assessment tasks are described; with explanatory quotations from lecturers and excerpts from the unit documentation. Students' perceptions of the context are then outlined. As outlined in Chapter 3, the unit was taught in two modes, an internal and external mode.

Syllabus and content

The specific topic forming the focus of this research was entitled *Cellular and Organismal Reproduction*. The content for the study topic was the same across both internal and external modes. The lectures and practicals focused on the processes of cellular reproduction, that is, the cell cycle, mitosis and meiosis, and how these relate to reproduction of whole organisms, and different lifecycle patterns. For students in both internal and external mode this was a two–week topic. Internal students attended three lectures and a practical session over the two–week period of semester, while external students studied the same material at home from print–based resources, and had a summary lecture and a practical during the residential school.

The topic was one component of a broad introductory first–year syllabus focused on covering the basics of a diverse and wide range of topics. The breadth of content in the unit was recognised as a potential issue by one lecturer: "there's a huge amount of content, a lot of jargon." Examination of the unit guides and practical manuals indicated that they were thorough, well organised and detailed documents. For example, the unit guides outlined learning goals and specific objectives for the students, provided a clear synopsis of major points, and outlined weekly study topics with clear links to the textbook (Campbell & Reece, 1999). The practical manual provided detailed and well structured instructions for activities, and contained questions targeting difficult concepts and guiding students' thinking.

Lectures

In both years of the study, lectures for internal and external students were based around teacher–led PowerPoint presentations, with very little student interaction. One of the lecturers described the institutional constraints of the unit associated with this teaching style as follows:

> ...we've got a sort of syllabus which has been agreed on by a vast committee to try and satisfy the needs of the whole faculty...and we even have committed into print what's actually going to be in all those lectures, so I'm basically teaching to a formula...even within the lectures I do all the first–year lectures on PowerPoint and that's a very rigid and inflexible way of doing things...
>
> (Lecturer 1, interview)

In year one of the study, the lecturer was very conscious of the amount of material to be covered and so tried to focus students on the important aspects of the topic by repeated comments along the following lines:

> We're going to talk about the two things on there, meiosis and fertilisation, they're the main things, just a diagram of that sort of simplicity is what you should be able to reproduce to explain what sexual reproduction is.
>
> So I'd really like you to remember and be able to reproduce that if somebody says "What are the sources of variation in sexual reproduction?
>
> Independent assortment, crossing over, random fertilisation, even if you can't tell me a whole lot more at least try to remember those three terms.
>
> (Lecturer 1, lectures)

The lecturer in the second year did not provide these cues, but observations of the lectures suggested that in terms of content, depth of explanation, and degree of student interaction, the lectures were similar across the two years. The main difference between lectures across the two enrolment modes was that the three lectures given to the internal students were condensed into one summary lecture during the residential school for the externally enrolled students.

Practical sessions

The stated focus of practicals in unit documentation was for the students to learn "some special technical (e.g., dissection) and intellectual skills (observation, interpretation, scientific method)" and to "reinforce what you have been learning in lectures"(First Year Biology Teaching Unit, 2001, p. iv). No project or problem–based activities occurred. Attendance at practicals was monitored and practical attendance was "used for overall assessment purposes in borderline cases" (First Year Biology Teaching Unit, 2001, p. iv). The practical schedules provided detailed instructions to students about the sequence and suggested timing of activities, which usually required drawn or written responses to questions. In the case of the practical associated with the Cellular and Organismal Reproduction topic for both modes, the activities were:

- Reading about the cell cycle and mitosis: 10 mins
- Preparing and examining root tip squash: 30 mins
- Counting cells and calculating timing of cell division: 20 mins
- Using pipe cleaner chromosomes to physically follow through and compare stages of mitosis and meiosis: 45 mins
- Examining demonstration material of asexually reproducing organisms: 20 mins
- Discussing tutorial question: 20 mins
- Completing ten multiple–choice self–quiz questions: 20 mins

Demonstrators (1 person per 12-15 students) provided instructions, explanations and feedback to students throughout the practical sessions.

Observations of practical sessions showed that internal students were engaged in the practical exercises to varying extents. Quite a few students were actively completing the exercises and talking about the subject matter, but a reasonable number of students were not, and many students left the practical session before the scheduled finish time of 5:00 p.m. The external students were similarly variously engaged, but there appeared to be more questions addressed to the demonstrators, a louder, more purposeful feel to the laboratory session, and very few of them left the relevant session before its scheduled completion. There were parallel differences between younger and older external students, which were articulated by one student as follows:

> younger kids are a lot different than we are...a lot greener than I am...and so from 15 in our group, three or four of them were fairly young and they do, they finish half an hour earlier than we do and I'm still struggling with the

> 3rd or 4th page not halfway through, still madly drawing. They seem to ignore the demonstrator half the time...but that's what happens
> (External focus group 1)

Assessment tasks

Like lectures and practicals, there was little choice associated with the assessment tasks in the unit. The three practical tests for internal students were held periodically throughout the semester and consisted of a number of short–answer questions, commonly associated with practical tasks, or interpreting diagrams or data. One of these practical tests covered material in the Cellular and Organismal Reproduction topic. The external students did not have a test associated with their practical work on the same topic. The two–hour final examination for the unit for all students consisted of fifteen multiple–choice questions plus twelve short to medium–answer questions. The latter were typically "briefly explain", "explain", "describe", "what is" tasks focusing on specific biological processes or entities, and emphasising recall of information presented in lectures and practical sessions.

In summary, the face-to-face teaching and learning context of this study for both modes comprised traditional teacher–centred lectures combined with predominantly illustrative practicals. This was supplemented for external students by printed resources outlining weekly study topics in line with the internal teaching schedule. The external students studied at home with no formal, regular contact with other students or staff, other than for the five–day residential period. Assessment of the cellular and organismal reproduction topic was by questions on a practical test and end–of–semester examination for internal students, and by the same examination questions for external students.

1a.ii: Students' perceptions of teaching and learning context

The following description of students' perceptions of their learning environment is a summary of the outcome of analysis of focus group interviews. The six internal focus groups and two external groups each contained from 6 to 12 participants. The focus groups discussed the students' perceptions of their learning context, in particular the teaching methods used, the amount and difficulty of the content in the unit, its perceived relevance and interest, and the students' views on the purpose of tertiary study (see Appendix D). The outcomes of the focus group interviews are summarised below according to these main areas of discussion, with some illustrative, representative quotations.

Teaching methods

The discussion about students' perceptions of the teaching methods was in terms of the lectures and practical sessions. Many students from internal and external focus groups, in general, thought that the lectures were worthwhile and well conducted, and that they provided essential background information for the practical.

S1: The lecturers cover a lot more and give you the full idea so you can understand step by step processes and things.
S2: The lectures give you the full scope of what you really need to know for the subject outline sort of thing like, goes through everything you need to know whereas the prac it might not be all in there...
S3: Lectures give you basic info and if you're having trouble the pracs are where you get it under control sort of thing.
S4: The pracs are a shocker if you didn't understand the lectures.
(Internal focus group 6)

S1: I definitely find lectures more useful because they only go for an hour so you can concentrate fully and um also, I guess in all science subjects they reckon it's better to have this hands on experience and get right into it but I think that I sort of learn better when I'm sitting down and just absorbing information and writing notes down and stuff like that and...then just take people's word for it that it actually happens, because that's why they're teaching you, instead of having to do it sort of thing...I find the lectures heaps more useful.
(Internal focus group 1)

Others, though, found the lectures boring:

S1: But um, I think how its taught, like because this dude he just puts it up on the screen and goes, "blah blah, blah blah", it goes right over your head and it makes an interesting thing, like its amazing really, it makes an interesting thing quite boring...
(internal focus group 1)

Some students from both groups complained of being "spoon-fed" in lectures, though these were in the minority. Some of the external students commented that the lectures were less effective than reading the material at home:

I: So how useful were the lectures?
S1: I would say less useful than the material provided in the study guide that we would cover at home, and the textbook. I don't know how it is for other people but I find as an external student I do learn mostly in a fairly self-determining sort of way, like I regulate my study, I learn principally from the material that is sent out to me. The residential school tends to be

> like a bit of a rush from one thing to another and you're bombarded by material.
>
> (external focus group 2)

Other external students, though, claimed that they were so busy with other commitments at home that they learned more in the residential school lectures. A number of the external students mentioned that the lectures were a useful reinforcement of what they had read, and that they performed an important function in both simplifying the complex textbook material, and also fleshing out some aspects of the content.

> S2: Well I'd like to say I operate on a different, practically almost the total opposite study regime to what these guys do...I find that the lectures are good for reinforcing your knowledge, but also as a secondary learning tool...It reinforces the stuff you've already got in your head and make sure you've got it right. And plus too, you pick up things in the lecture that might not be discussed in the textbook or in the study guide...a lot of them discuss new material and discuss the material in a wider sense so they're fleshing it out so you get more information in a lecture sometimes than you do just off your textbook.
>
> I: In the particular lecture attached to that part of the course was that the case or was that a summary of what was in the textbook?
>
> S2: A little bit of both, I think...but I guess because mitosis and meiosis is such a structured thing, they can't really flesh it out any more than they already had, so in that sense it was a bit of repetition, but it was good just to concretise that information in your own head.
>
> S3: I'm sort of a person, where this is where I get most of my study done—here at the res school. Because I've got such a big workload at home with my occupation. I do 60 hrs a week and I'm on a full study load as well
>
> I: How do you do it?
>
> S3: I dunno. Coming up here and actually going to the lecture and reinforcing the minimal notes that I've actually done at home and...when I get here ...it's just really helpful because you're not just reading out of the book, where I admit I get distracted, and sort of pack it in half the time...that particular lecture I found was just so helpful because I just got a real good grasp of the concepts.
>
> S5: I probably agree with the first two—I do most of my reading and stuff at home so when I come here the lectures are just really repetition of what I've already read.
>
> I: Is that a waste of time ?
>
> S5: It's not really a waste of time—like I find it good just to go over it.
>
> S1: I wouldn't have said that lectures are a waste of time—at all—like sometimes they're really good at kind of putting things into context and clarifying but I don't think it's a primary mode of learning for external study.
>
> (external focus group 2)

Students could not offer suggestions for improvement to the lectures, and most were sceptical or unenthusiastic about a more interactive lecture format. To these students, talking, questioning and answering were activities suited to the much smaller practical groups with a more readily accessible, well known demonstrator.

> I: So do you think there's a place in the lectures for asking questions, getting the students to ask some questions, having a more interactive type...
> S1: There is but nobody really does...you don't really ask questions in the lectures because you think "oh well if I really can't think of it I can ask it in the prac" so you just sort of let it go over—yeah.
> I: What about lecturers asking the questions?
> S1: Um, yeah, that's another thing, people sort of aren't game enough to shout out an answer. They just sort of sit there thinking "Oh he's talking to us now...Right! Yeah."
>
> (Internal focus group 2)

There was a clear difference between the perceptions of internal and external focus groups to the practical work associated with the topic. An extremely strong repeated theme from the internal focus groups was that the practical sessions in general, including the one in the relevant topic, were very boring:

> I: OK, yep, um so if you had to speak on behalf of all the other students, doing today's prac, what do you think they think of the content and the pracs and lectures
> S1: It depends on which ones you talk to.
> I: I know, but give me an idea of the range.
> S1: Oh well, I reckon a lot of the guys'd say "Oh it's a load of crap [laughter] yeah we don't need half of this, blah blah blah".
>
> (internal focus group 3)

A number of students made comments along the lines that by the end of the day they "just want to get out".

> I: So do you think there are other students in the unit that don't think its interesting or relevant...?
> S1: I think it's bad when you're like playing with pipe-cleaners and paperclips and you're going 'Oh this is just taking up my time I'm going to leave'.
> S3: Its Thursday afternoon everyone just wants to get out.
> S1:Yeah you just want to get out.
>
> (internal focus group 3)

The pipe-cleaner exercise was viewed by many students as boring and removed from the real world, but several students also acknowledged that the exercise did reveal areas of confusion about meiosis and help to clarify their understanding:

> S1: I might be a bit stupid, and it was very boring, but I was sort of half glad because I was a little bit sketchy on it the first time we went round...
> S3: Well I think the pipe-cleaner bit, despite what everyone has said, has reinforced it for me...
> S1: Yeah I'd agree it was very useful but still you do feel like a bit of a kid with your play dough and [laughter] squiggles and stuff.
> S2: It's just that we did it for 2 hours, played with pipe-cleaners for 2 hours. I think that an hour or an hour and a half might have been good.
> (internal focus group 1)

The external groups did not express the same discontent with their practical sessions, and they generally expressed satisfaction with the activities and the practical session's contribution to their learning.

Content amount and difficulty

When asked about the amount of content in the unit and topic, many students thought it was "OK" with some commenting that it was too much. Some students assumed that that is just the way it is at university:

> S1: It is a lot to remember but you kind of get that, so um sort of expect that being at university.
> (internal focus group 3)

Similarly, there were few strong messages about the material being too difficult. Many recent school leavers in the internal cohort complained about the content being a repetition of what they had studied at school and in the first semester biology unit, but acknowledged that the content had to be covered for other students who did not have the same background.

> S1: these are sort of like catch-up units...some people haven't done Bio in Yr 12 and some people have, some people are going "yep, done this before, its boring, yep, basically got most of this anyway" and other people haven't done it and its all new to them so you've got the 2 extremes...its not sort of really specific to the degree you want to do at the end so...
> S2: Yeah but like you've got to take into consideration the people who haven't already done it, so it's hard from the University's perspective.
> (internal focus group 3)

Relevance and interest

There was some contrast evident between the views of mature–aged (mostly external) and younger (mostly internal) students on the relevance of the content. Some recent school leavers could see immediate relevance to their lives or studies, but many did not express this view, rather perceiving that they were collecting the basics which they took on trust as being relevant to future units or employment contexts.

> S1: I think as I said before it gives you the basics of what we'll need for further studies and without that there's no point in trying to attempt your further studies.
>
> (internal focus group 5)

> S1: I think eventually when we do something else in $2^{nd}/3^{rd}$ year and then we'll see how it works—that's the thing, like you're just learning this thing at the moment and its not really fitting into anything as of yet.
>
> (internal focus group 6)

One focus group (dominated by Rural Science students) expressed the strong desire for the content to be more directly related to their degree program:

> S1: Maybe if it was a little, like, applied to some—like we could actually see some sort of outcome...instead of talking just about the chromosomes we could like go through and see like after meiosis the...different sort of outcomes...because like applying it to something like cattle or something so we could see how the variance comes out?
> S1: Um, its kind of hard. I'd like it , because I'm doing rural science, I'd like it to be a little bit more rural outlook and stuff because I've done all this in Yr 11 & 12 so I'm just sort of sitting here going OK, we'll just look over this again, I'd like to start getting in to what I'm going to be going in to.
> S2: It's all just, it's nothing to do with what we thought we were doing...
> S1: [interrupt] so far we've hardly even looked at...we've looked at a bit of soil and some plants and that's about it we haven't looked at a lot of stuff.
> S3: First year stuff's so boring it's just, it's got nothing to do with rural science at all, really.
>
> (internal focus group 3)

When the question of relevance was raised with the external focus groups, the same perception that the material was relevant in some, as yet unclear, way to later units was expressed. There was also a strong view among many students of a more immediate personal relevance and interest:

> S1: relevance—well I guess, its relevant to life; whether its relevant to vocations—it depends what you end up doing, doesn't it, but um certainly its relevant to me in that it's part of life so its very interesting.
> S2: to know that every single cell in our entire body—every single cell in every other thing in the world undergoes the same process is really kind of profound.
>
> (external focus group 2)

Purpose of tertiary study

In discussing their perceived purpose of tertiary study, a highly instrumental outlook emphasising employment and financial security was very apparent in internal students, but with some students admitting to no clear purpose at all:

> S1: I wasn't sure what I wanted to do so I just came to uni.
>
> (internal focus group 4)

Among internal students, little mention was made of other purposes for studying. In the external focus groups, discussion of the purpose of tertiary education also featured instrumental benefits, but many students also emphasised personal satisfaction, the pleasure of studying and finding out about areas of interest to them:

> I: And my last question, is...I'll broaden it out a bit, is what do you see as the purpose of tertiary education?
> S1: Money! [Laughter]
> S2:What, for us or them? [more laughter]
> I: No for you—what are you wanting to get out of it?
> S3: Like I said before, apart from the bit of the paper, you know, it's only a degree, I've realised, just getting the brain working and getting that bit of knowledge and exploring the world before and having that retained knowledge so I can get the personal satisfaction of that degree...It's a quality of life, really.
> S4: It's a challenge for me being older...changing career, it's a different point, we're at a later stage where a lot of people do change careers a lot during their lifetime. It's a challenge to do with external study and maturity, and its just the satisfaction of doing something and finishing you know, Oh I passed that, that's really good.
> S1: My motivation is a lot more mercenary than that, because, um, like its just harder now to get ahead, being a person who is uneducated. You can't get the good jobs and the money's just not there. So it's a job security thing.
>
> (external focus group 1)

In summary, students' perceptions of their learning context, as articulated in a number of focus groups, were quite diverse. Students across internal and external student sub-groups expressed some similar views about the lectures and content, as well as differences in interest and perceived relevance.

Summary 1a

This section describes the details of the teaching and learning context, as a necessary setting against which to examine the learning approaches adopted and outcomes achieved. This learning setting was investigated from two perspectives: observations of the teaching and institutional characteristics, and explorations of students' perceptions of the learning context. From the first perspective, the context represented traditional teacher–centred lectures, and practical activities, aimed at covering a broad range of content to feed into a broad range of later sub-disciplinary areas. Assessment focused on recall and understanding of concepts covered in the unit.

Both external and internal student focus groups expressed overall satisfaction with the lectures, alongside some perceptions of being bored or "spoon-fed". The students were also generally accepting and non-critical about the amount of content in the unit and its difficulty. A large majority of the students expressed an instrumental purpose to their study, including those students (predominantly but not only external students) who were also studying for their own personal satisfaction. Some differences in the perceptions of the two subgroups were apparent, though. While external students held mostly positive perceptions about the practical, many of the internal students found the practical session boring, but some aspects of it useful as well. In general, many internal students found the topic to be largely irrelevant to their immediate concerns, while many external students in the focus groups found the topic personally relevant and interesting.

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

In this section, the results from students' responses to the topic–specific learning approaches questionnaire (MSPQ) are presented. This line of inquiry followed five research questions:

- 1b.i: How reliable and valid is the MSPQ in the study context?
- 1b.ii: What is the relative difficulty of the items on the MSPQ?
- 1b.iii: What is the distribution of deep and surface approaches across the total sample?
- 1b.iv: Do internal and externally enrolled students studying in the same unit exhibit differences in learning approach?
- 1b.v: How do learning approaches relate to other student variables of age and gender?

In addressing these questions, students' responses to the MSPQ were analysed from both years of the study, and from both the internal and external cohorts.

1b.i: Reliability and validity of the MSPQ

The results of the reliability and validity tests of the MSPQ scales in the study context are presented here. These include: (i) standard factor and (ii) Cronbach reliability analyses to allow comparison with previous studies. This is followed by (iii) Rasch measurement modelling as a novel test of reliability and validity, and for its other advantages in establishing interval–level data. Finally, the results from the validity check questionnaire in relation to MSPQ responses are presented. The sample on which these results are based involved 306 students over two years. Further details relating to the sample were outlined previously in Chapter 3.

Factor analysis

The results of the exploratory factor analytic procedure that was undertaken showed many substantively congruent factor solutions to the students' responses to the MSPQ. The Varimax solution for all students is reported here as the simplest and representative factor solution, and because the direct quartimin solutions indicated no correlation between factors. The screeplot of the initial factor solution for all students' responses to the MSPQ is shown in Figure 4.1.

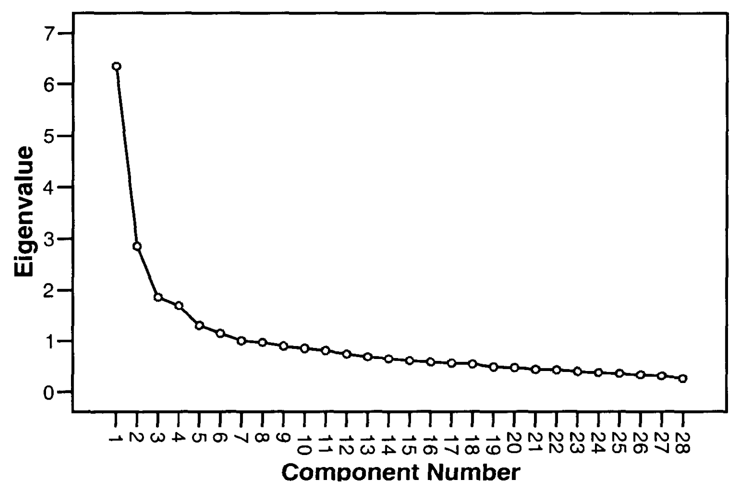


Figure 4.1: Screeplot of initial factor solution to MSPQ responses

The most marked change in slope of the screeplot occurs at component three. This suggests that two components explained most of the variance and should be extracted. The rotated component matrix for the two–factor solution suggested by the screeplot is provided in Table 4.1.

Table 4.1: Varimax rotation of two–factor solution to responses on the MSPQ: all students

Item	Surface/Deep Scale	Component	
		1	2
2	D	.725	
4	D	.514	
6	D	.499	
8	D	.427	
10	D	.683	
12	D	.607	
14	D	.689	
16	D	.392	
18	D	.772	
20	D	.702	
22	D	.663	
24	D	.611	
26	D	.641	
28	D	.481	
1	S		.342
3	S	-.450	.465
5	S		.491
7	S		.441
9	S		
11	S		.394
13	S		.496
15	S	-.465	.511
17	S	-.473	.526
19	S		.435
21	S	-.377	.436
23	S		.477
25	S	.451	
27	S		.564
% Variance		*22.6*	*32.9*

Note: Rotation converged in 3 iterations, coefficients less than 0.3 were suppressed.

Table 4.1 shows that all the items from the deep scale loaded solely and strongly on Component 1, which also included item 25 from the surface scale. All items from the surface scale except 25 and 9 loaded strongly on the second component. Although the amount of variance explained by the two factors (33%) is somewhat less than the 50-60% of variation typically explained by factors in factor analysis (Meyer & Shanahan, 2003, p. 9), the factor structure in Table 4.1 provides reasonable support for the two constructs of deep and surface learning approaches in the study context. The variance explained is approximately consistent with the 37% (for three factors) found for the same questionnaire in a first–year science context (see Chapter 3).

Reliability

The reliabilities of the deep and surface scales of the MSPQ, as well as the entire 28 item Learning Approach scale were also examined, for each year of the study and for the internal and external subgroups separately. These results are outlined in Table 4.2.

Table 4.2: Cronbach alpha reliabilities for the MSPQ and its deep and surface scales

Year	Enrolment type	MSPQ "Learning" scale (28 items)	Deep scale (14 items)	Surface scale (14 items)
1	internal	.72	.81	.67
	external	.76	.88	.68
2	internal	.78	.85	.67
	external	.79	.90	.62
Both Yrs: all students		.75	.87	.69

The coefficients in Table 4.2 indicate moderate reliability for the surface scale, but good reliability for the deep scale. Of particular note is the good reliability of the entire MSPQ as a single scale, here called for convenience the "Learning" scale. In addition, reliabilities were very similar across both years and enrolment types within the study sample.

Rasch rating scale analysis

Like the factor analysis, rating scale analysis of the different MSPQ scales yields validity and reliability indicators of the scales of the MSPQ. The rating scale analyses were conducted in addition to the factor analysis to provide an independent assessment of validity and reliability of the deep and surface scales, particularly given the relatively low percentage of variance captured by these two scales in the factor anlaysis. The Rasch validity and reliability indicators are reported in Table 4.3, which includes analyses of all three scales.

Table 4.3: Item and student statistics from rating scale analyses of the MSPQ scales

Statistic		"Learning" scale (28 items)	Deep scale (14 items)	Surface scale (14 items)
Item estimates	Mean	.00	.00	.00
	Standard Deviation	.41	.65	.38
	Separability	.66	.82	.60
Item infit mean square	Mean	1.00	1.01	1.00
	Standard Deviation	.15	.18	.10
Item outfit mean square	Mean	1.01	1.00	1.01
	Standard Deviation	.17	.19	.10
Item infit t	Mean	-.02	-.06	.00
	Standard Deviation	2.10	2.34	1.30
Item outfit t	Mean	.05	-.10	.09
	Standard Deviation	1.78	1.95	1.06
Student estimates	Mean	.04	-.04	.12
	Standard Deviation	.40	.93	.49
	Separability	.79	.88	.72
Student infit mean square	Mean	1.02	1.01	1.01
	Standard Deviation	.58	.72	.60
Student outfit mean square	Mean	1.01	1.00	1.01
	Standard Deviation	.58	.72	.60
Student infit t	Mean	-.27	-.21	-.20
	Standard Deviation	2.22	1.65	1.68
Student outfit t	Mean	-.19	-.13	-.09
	Standard Deviation	1.72	1.32	1.31

Notes: $N = 306$

Table 4.3 indicates that the item separability indices are from 0.60 (surface scale) to 0.82 (deep scale), and the student separability indices are from 0.72 (surface scale) to 0.88 (deep scale). These values represent moderate separability (analogous to reliability) of the deep and learning scales, and somewhat lower but adequate separability of the surface scale (see e.g., Waugh, 1998), which is therefore less sensitive in distinguishing between students.

For students and items on all scales the mean infit mean squares and mean outfit mean squares are close to one, and infit and outfit t values are close to zero. These values indicate that all three scales fit the measurement model. The fit and item maps from the single Learning scale are presented below, therefore, as this encompassed all the surface and deep items.

The infit and outfit mean square values for each of the items on the questionnaire are presented in Figure 4.2. The dotted line at 1.30 represents one of the commonly used cut-off points for acceptable fit, indicating the point of 30% more variation between observed and expected responses than would be predicted by the model. The other cut-point at 0.78 represents 22% less variation than predicted between observed and predicted responses (Adams & Khoo, 1993).

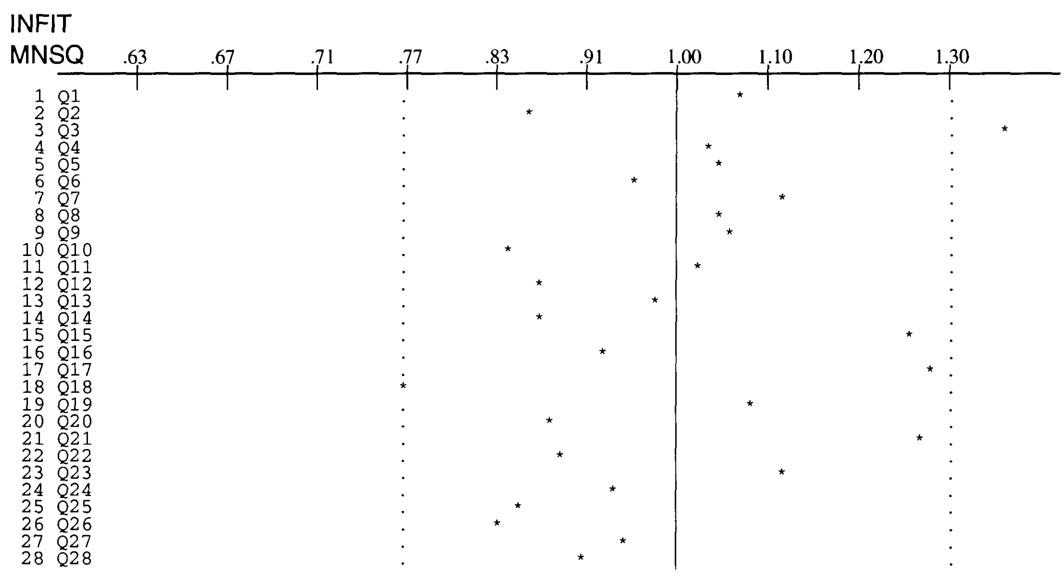


Figure 4.2: Item fit map for all 28 items of the MSPQ

The mean square values for the items in Figure 4.2 fall within the commonly used 0.78-1.30 range, except for item 3. This is a surface strategy item relating to restricting study to what is specified in class or unit materials. This item, though, is still within the more relaxed 0.6-1.40 range considered acceptable for Likert scales (Bond & Fox, 2001, p. 179). These item fit statistics suggest again that all the items fit the measurement model used in the analysis.

The student ability and item threshold difficulty estimates from the rating scale analysis are shown on a common scale in Figure 4.3. As mentioned in Chapter 3, the term student "ability" in this sense pertains specifically to the extent to which they have agreed with the items, that is, their agree-ability. The student and item estimates in Figure 4.3 provide information on a number of aspects of the questionnaire, including the spread of the items along the scale, the appropriateness of the quantity and difficulty of the items to the student group, and separability indicators.

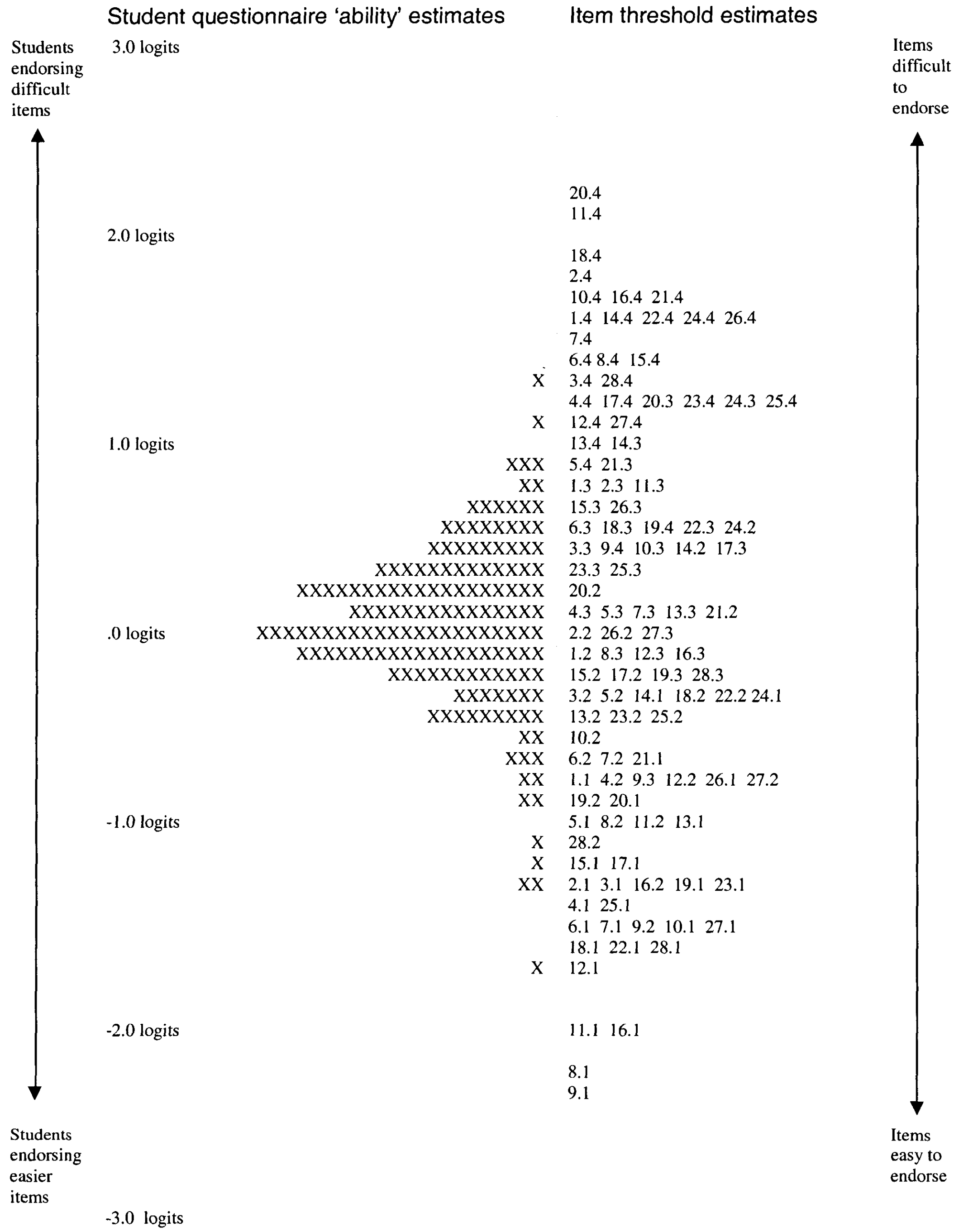


Figure 4.3: Student ability estimates and item threshold estimates for students' responses to the MSPQ. Each X represents two students, $n = 302$

As shown in Figure 4.3, all the item threshold values are ordered, that is, step 1 on any item is more easily agreed with than step 2 and so forth. This suggests that all the items conform to the requirements of the model, as is shown by the item fit map (Figure 4.2). The distribution of student and item scores shows that the lowest and highest levels of item thresholds span the student ability estimate difficulties. The greater range of estimated item threshold difficulties compared to student abilities indicates that there are enough items on the questionnaire to distinguish between student performance, and that questionnaire items are well targeted at the right level of difficulty for first–year university students. The students' performance in response to the items was well spread, indicating good separation among both students and items.

Validity check

The results presented above relate to the validity and reliability of the deep and surface constructs used in the MSPQ. The validity of students' responses to the MSPQ in relation to the target study context was examined by a short three–item questionnaire (Appendix G). Responses to the validity questionnaire indicated that 85% of students remembered the section of the unit, and that 89% of students agreed that their "approach to study in the *Cellular and Organismal Reproduction* section has been typical of the rest of BIOL 120 so far". Only four students had both forgotten the section of the unit and reported a different learning approach to the subsequent topic. This indicates that for the vast majority of students the responses to the MSPQ were indicative of their learning approaches in the target context.

In summary, the results of the factor analyses provide reasonable support for the validity of the deep and surface scales of the MSPQ in this study context and across the year and enrolment subgroups of the sample. The reliabilities of the deep and surface scales are similarly supported, with the entire 28 items also forming a reliable unidimensional scale overarching the deep and surface subscales. The results from the rating scale analyses outlined above are consistent with the results of the factor and Cronbach reliability analyses. They support the construct validity and reliability of the overarching Learning scale and the deep and surface scales, while showing that the surface scale is less reliable than the deep scale. Finally, the students' responses to the MSPQ do seem to be a valid representation of their learning in the study context, within the limitations of self–reporting discussed in Chapter 3.

1b.ii: Relative item difficulty

The relative difficulty of individual items of the MSPQ is shown in Table 4.4.

Table 4.4: Item difficulties (in logits) for the MSPQ, in order of most difficult to endorse (positive values) to easiest to endorse (negative values)

Item #	Scale*	Item	Mean item difficulty
24	ds	I spend a lot of free time finding out more about interesting aspects of this topic	.94
14	dm	I find that studying this topic is as interesting as a good novel or movie	.83
20	ds	I find most aspects of the section interesting and spend extra time trying to obtain more information about them	.67
21	sm	I almost resent having to study topics like this, but feel that the end results will make it all worthwhile	.56
1	sm	I am concentrating on studying this section of the unit largely with a view to the job situation when I graduate rather than because of how much it interests me	.39
26	dm	Studying in this section has challenged my views on how the world works	.38
2	dm	I find that studying this topic gives me a feeling of deep personal satisfaction	.36
15	ss	I restrict my study to what is specifically set, as I think it is unnecessary to do anything extra	.19
18	dm	I become increasingly absorbed in my work in this section the more I do	.14
17	sm	I think it's only worth studying material that I know will be examined	.12
22	dm	I believe strongly that my main aim in studying this section is to understand it for my own satisfaction	.11
3	ss	I think browsing around is a waste of time, so I only study seriously what's given out in class or in the outline of the topic	.03
10	dm	I feel that this topic became interesting once I became involved in studying it	.00
11	ss	In studying this section, I am focussing more on the factual content than the theoretical material	.00
6	dm	While I realise that ideas are forever changing as knowledge is increasing, I need to discover what is meaningful for me in this section of the unit	-.02
23	ss	I find it best to accept the statements and ideas of my teacher(s) and question them only under special circumstances	-.05
25	sm	I am prepared to work hard in this section, because I feel it will contribute to my employment prospects	-.07
5	sm	I am worried about how my performance in this section will affect my overall assessment	-.12
13	sm	I worry that even if I work hard for this section, the assessment might not reflect this	-.14
7	ss	I learn some things by rote, going over and over them until I know them by heart	-.21
4	ds	While I am studying this section of the unit, I think of real life situations to which the material I am learning would be useful	-.29
27	ss	I am very aware that teacher(s) know a lot more than I do, so I concentrate on what they say is important rather than relying on my own judgement	-.36
8	ds	In reading new material for this unit, I find that I'm continually reminded of material I already know, and see the latter in a new light	-.42
16	ds	I try to relate what I have learned in this topic to material in other sections	-.43
12	ds	I find that I have to do enough work on this section until I personally understand the material, before I am satisfied	-.44
28	ds	I try to relate new material, as I am reading it, to what I already know on that topic	-.49
19	ss	I learn best in this section from teacher(s) who work from carefully prepared notes and outline major points neatly on their whiteboard/slides	-.64
9	sm	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	-1.03

*dm = deep motive, ds = deep strategy, sm = surface motive, ss = surface strategy

The item difficulty estimates in Table 4.4 were established by the item difficulty estimates from the rating scale analysis, and are listed in order of decreasing difficulty. These show that eight of the ten easiest to endorse items were strategies and of these, half were deep and half surface strategies. However, by far the easiest to endorse item was item 9; a motive item that doing well in the section leads to a good grade in the unit. Seven of the ten hardest to endorse items were motives. Again, of these items, approximately half were deep and half surface. Both deep and surface scales covered a full range of item difficulties, indicating no apparent relationship between item difficulty and deep/surface scales for the entire sample.

In summary, the relative item difficulties established by the rating scale analysis indicate a difference between students' responses to motive and strategy items, in terms of their endorsement. It seems that many students found it considerably easier to agree with items pertaining to behaviours (strategies) rather than attitudes (motives).

1b.iii: Distribution of deep and surface approaches across the total sample

Analyses of the distribution of deep and surface learning approaches in this section are based on the deep and surface ability estimates from the rating scale analysis of the learning scale. As outlined in Chapter 3, ability estimates are a preferable alternative to raw factor scores as a measure of students' approaches to learning. This is because the ability estimates take into account student/item interaction and because they provide interval–level data which are amenable to parametric statistical analysis.

This subsection begins with results pertaining to the homogeneity of the samples across both years, and then presents a scatterplot and correlation for the deep and surface ability estimates across the total sample. The deep and surface ability estimates are then banded into five ability groups to facilitate comparison of distributions, and finally, results from cluster analysis of finer scale patterns of responses to the deep and surface scales are presented.

Homogeneity of sample

The mean ability estimates obtained from both years of the study and from internal and external students were compared to test for homogeneity across the two years of the study with respect to deep and surface learning approaches. The results from this analysis are shown in Table 4.5.

Table 4.5: Comparison of mean deep and surface approach estimates in Year 1 and 2, for internal and external students

Enrolment	Learning approach ability	Year of study	*N*	Mean	Std. Error Mean	*t*	d.f.	Sig. (2-tailed)
Internal	deep scale	1	86	-.09	.07	1.96	220	.052
		2	136	-.30	.07			
	surface scale	1	86	.18	.05	-1.09	220	.28
		2	136	.25	.04			
External	deep scale	1	50	.50	.14	-.54	74	.59
		2	26	.64	.21			
	surface scale	1	50	-.11	.07	.07	74	.94
		2	26	-.12	.08			

Table 4.5 shows no significant differences between mean deep and surface learning approach estimates between the two years of the study, for either of the enrolment subgroups. This suggests that Year 1 and 2 samples were relatively homogeneous with respect to learning approaches. In particular, comparing mean learning approach estimates for external students shows no evidence of bias arising from the lower response rate in Year 2, relative to Year 1 responses. This result supports the comparability of these two samples from the same population, and hence the pooling of the two samples from different years in subsequent analyses.

Relationship between deep and surface scales

The student deep and surface ability estimates were examined to explore the overall relationship between them. The distribution of deep and surface approach ability measures is shown in Figure 4.4.

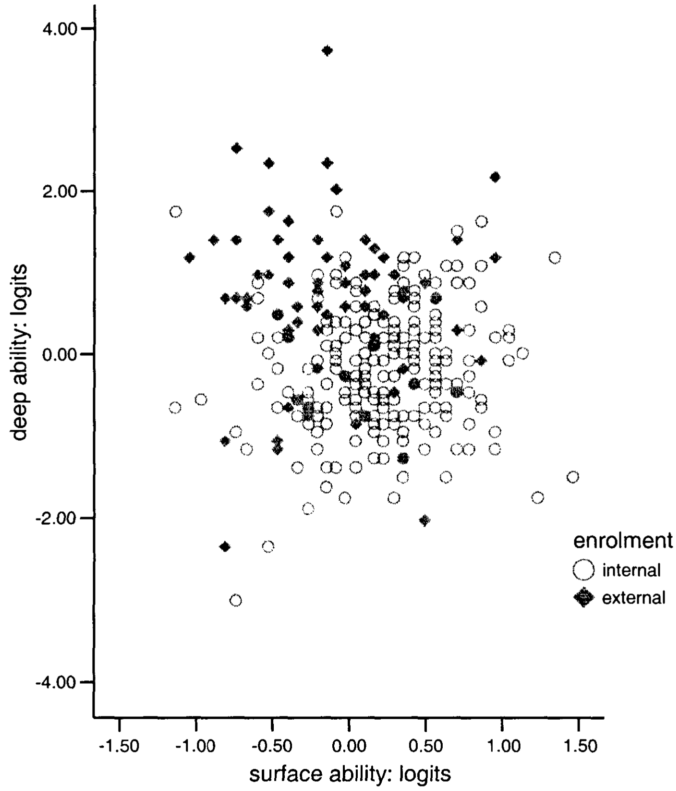


Figure 4.4: Scatterplot of deep and surface learning approach abilities for internal and external students

As is suggested by the distribution of points in Figure 4.4, for the group as a whole there is no association between deep and surface approaches (r = -.09, N = 301, p = .11). This result indicates that deep and surface approaches, at least as they are articulated and defined by the MSPQ, are independent ways by which students engage with their learning. The implication is that students may adopt different combinations of deep and surface approaches, including essentially mixed approaches. Students in the bottomleft corner of Table 4.5, for example, have reported neither a predominantly deep nor surface approach; those in the high–density middle have reported average scores on deep and surface approaches, and those in the topleft corner have reported a predominantly deep approach.

Also indicated by Figure 4.4 are the different ranges of the deep and surface scales. For example, an ability measure of 1.5 logits is very high on the surface scale, but not as extreme on the deep scale. To aid in assessing the distribution of deep and surface approaches and later comparisons of approach and outcome, the deep and surface abilities were each divided into bands, which are described below.

Deep and surface ability bands

Five ability bands were established for the deep and surface ability measures. The top 10% of the deep and surface ability estimates were defined as very high, the next 20% as high, the middle 40% as medium, the next 20% as low and the bottom 10% as very low. The counts in each of these bands are shown in Table 4.6 below.

Table 4.6: Description and distribution of deep and surface ability bands

Descriptor	% of total responses in band	Count for deep bands	Count for surface bands
Very Low	10	29	29
Low	20	59	62
Medium	40	121	120
High	20	61	62
Very high	10	31	28

The counts in Table 4.6 vary slightly from the percentage definition because minor adjustments were made to accommodate band cut-points occurring within a group of identical estimate measures. The number of students in each of the possible combinations of deep and surface ability bands is shown in matrix form in Table 4.7.

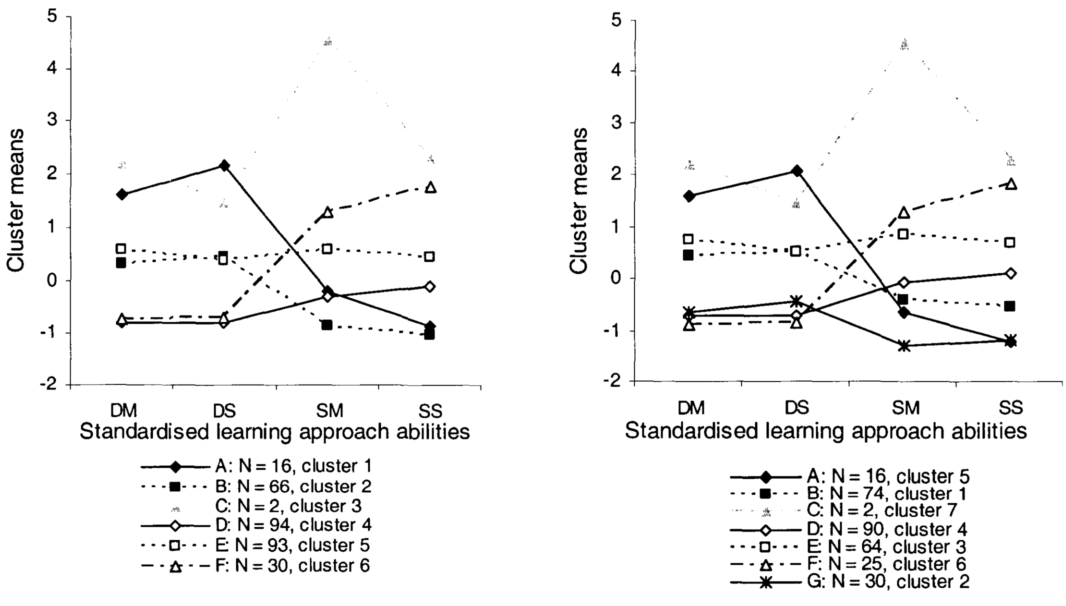
Table 4.7: Number of students in each combination of deep and surface ability bands

		Surface ability bands				
		v. low	low	medium	high	v. high
Deep ability bands	v. low	4	3	8	7	7
	low	4	13	23	10	9
	medium	10	34	53	21	3
	high	5	8	26	17	5
	v. high	6	4	10	7	4

The pattern of distribution in Table 4.7 shows that 91 students (those in the greyed cells) were in the same deep and surface ability bands. This represents about one third of the sample. These students have reported mixed deep and surface approaches to learning in their responses to the MSPQ, with those in the low bands for each reporting little of either approach, and those in the high bands reporting considerable use of both approaches. The most frequently represented category is the medium band for both approaches. Other frequently represented categories are those indicated by diagonal shading, where students scored one band higher for one or other of the approach categories. Relatively few students showed evidence of strongly predominantly deep or surface approaches, that is, were in the high surface bands and low deep bands, or vice versa. These results show the distribution of and relationship between deep and surface approaches, as identified by the MSPQ, at a broad scale. The relationships between these two learning approaches at a finer scale are indicated by the results of cluster analyses of learning approach variables.

Cluster analysis

Results from the *k*-means cluster analyses for the group as a whole are shown in Figure 4.5. This figure shows the different clusters of students identified in two relatively stable successive solutions, and the cluster-mean scores for each of the learning approach variables. The different clusters demonstrate the different patterns of relationship between deep motive, deep strategy, surface motive and surface strategy variables from the MSPQ, in the student sample. The clusters have been reordered to aid interpretation, with congruent clusters identified as groups. Because the analytic procedure groups the cases on the basis of their relative homogeneity, the clusters reflect the characteristics of their typical constituent students.



a: Six cluster solution

b: Seven cluster solution

Figure 4.5: Six and seven cluster solutions for deep motive (DM), deep strategy (DS), surface motive (SM) and surface strategy (SS) abilities: all students

As is indicated in Figure 4.5a and b, the six and seven cluster solutions are similar in many respects. Both solutions identified a number of stable, major groups which are:

- A: (about 5% of cohort) with high deep and low surface cluster-means
- B: (about 25% of cohort) with about average deep and low surface cluster-means
- D: (about 30% of cohort) with low deep and about average surface cluster-means
- F: (about 10% of cohort) with low deep and high surface cluster-means

In addition, both solutions identified a group of two students (C) with high deep and extremely high surface cluster-means. The six cluster solution isolated a large group (E) of about 30% of the sample with a very flat profile comprising very similar, and average cluster mean scores for all variables. This pattern persisted in the seven cluster solution (E) but with fewer members, and the remaining students are grouped into an additional cluster (F) with low deep and even lower surface cluster-means.

These cluster analyses provide evidence for groups of students adopting all possible combinations of deep and surface learning approaches. The largest proportion of students (group D) seems to have adopted relatively little of a deep approach to their learning, with somewhat more reliance on surface motives and strategies. Another large group (E) is likely to comprise members adopting more or less mixed approaches to learning, with similar scores on deep and surface variables. Other smaller groups represent contrasting patterns of high deep and low surface approaches (A), and low deep and high surface approaches (F).

In summary, this section has demonstrated the homogeneity of students' responses to the MSPQ in the two separate years of the total sample. Correlation analysis of pooled data from both years shows no association between the deep and surface approaches. Five ability bands were established for both the deep and surface scales, and a large proportion of students have reported adopting a mix of deep and surface approaches. Cluster analysis of deep and surface motives and strategies established groups of students adopting several combinations of deep and surface learning, and showed that many of the students adopted either a combination of low deep and moderate surface approaches, or relatively evenly mixed approaches to their learning. These differences which were found across the whole sample were examined in more detail, in comparing internal and external cohorts.

1b.iv: Comparison of internal and externally enrolled students

This subsection presents the results of comparisons of learning approaches across internal and external students. Although studying the same syllabus and sitting for the same examination, these two groups of students experienced quite different learning contexts, which were outlined earlier in this chapter. This makes a comparison of their learning approaches of particular interest. The results of correlations between deep and surface approaches for internal and external students are presented first, followed by comparisons of mean deep and surface approaches across both groups. The ratio of internal to external students in the five ability bands for both approaches is then illustrated. The results of a Rasch differential item functioning (DIF) analysis are then presented, and finally, results of cluster analyses of finer–scale patterns of response to the MSPQ are presented for internal and external groups separately.

Possible differences in association between deep and surface approaches between internal and external students were examined using Pearson product-moment correlations. These showed no correlation between surface and deep learning approach for either internal (r = .06, n = 222, p = .34) or external students (r = -.05, n = 76, p = .65). So these approaches were independent in both enrolment types.

The mean deep and surface abilities for internal and external students were compared using independent samples t-tests. These tests indicated significant differences between means for both learning approach scales, which were suggested by the structure of the data in the scatterplot (Figure 4.4 above). For the deep scale, the mean for internal students (-0.22) is significantly lower than for external students [0.55, t (296) = -6.9, $p < .001$], and this was a large effect ($\eta^2 = 0.14$). For the surface scale, in contrast, the mean for internal students (0.23) is significantly higher than for external students [-0.12, t (296) = 5.70, $p < .001$], and this was a medium effect (η^2= 0.11). These results show that external students reported more use of deep approaches than internal students, while, conversely, internal students reported adoption of a more surface approach than external students.

These differences in the learning approaches of internal and external students are reflected in Figure 4.6 below, which shows the ratio of internal to external students in the five deep and surface ability bands. Also shown in Figure 4.6 is a line indicating the ratio of internal to external students for the whole sample (2.9:1).

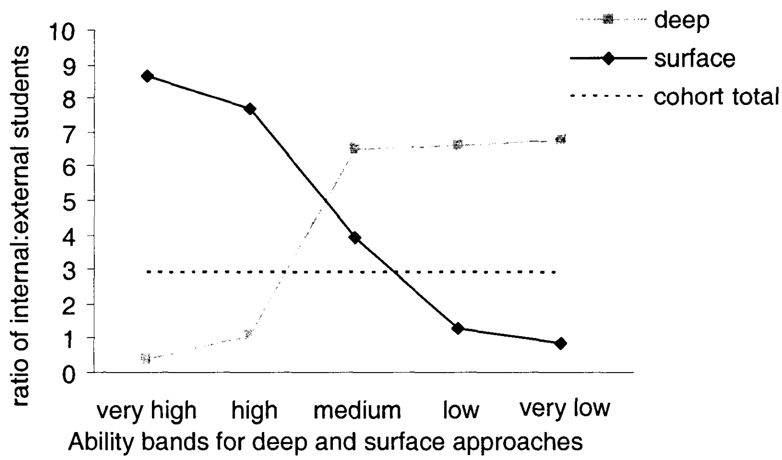
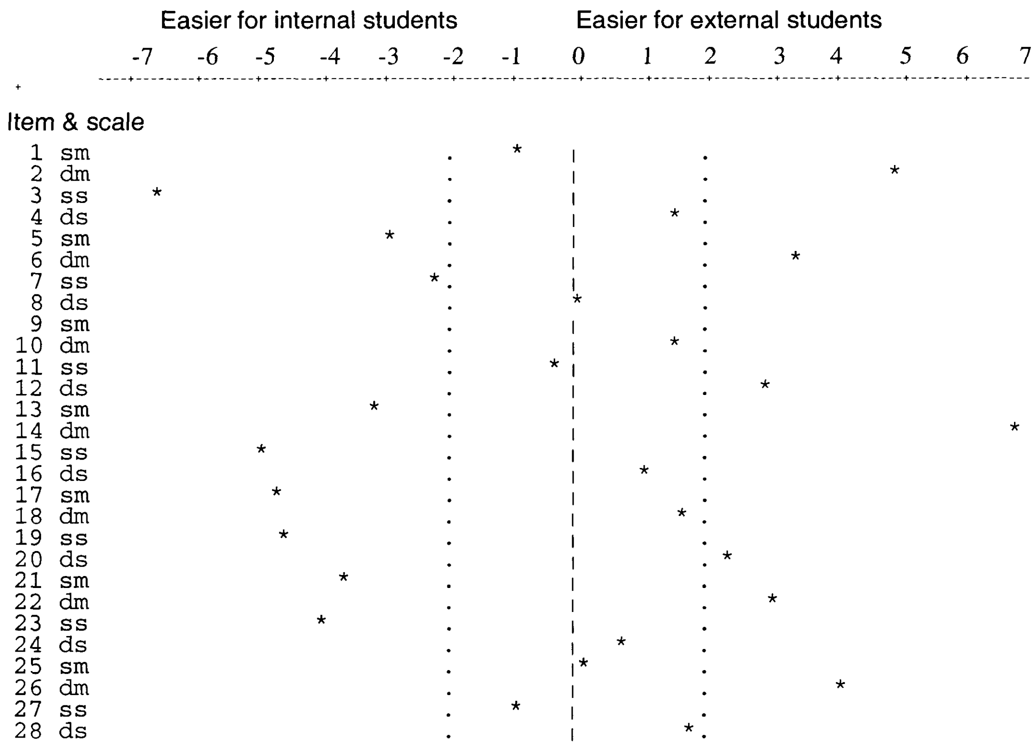


Figure 4.6: Ratio of internal:external students in five ability bands, for deep and surface approach ability measures

External students have a greater proportional representation in the low surface and high deep ability bands, while the internal students are represented relatively more frequently in the high surface and medium to low deep ability bands (Figure 4.6). These differences were significant for both the surface (χ^2 (4) = 33.72, $p < 0.001$) and deep approaches (χ^2 (4) = 63.78, $p < 0.001$). These differences between learning approach abilities of internal and external groups were examined in more detail using Rasch measurement techniques to examine responses to individual items of the MSPQ.

Rasch Differential Item Functioning analysis

Rasch DIF analysis was conducted to detect differences in responses of the external and internal groups to individual items of the MSPQ. The results of a DIF analysis of individual items on the MSPQ are shown in Figure 4.7, with items outside the tramlines showing DIF. Starred items to the right of the figure are those easier for external students to endorse, while starred items to the left of the figure are those endorsed more easily by internal students.



Note: Results for item 9 did not appear on this output. It had the lowest item difficulty and may have exceeded the range that could be handled by the analysis/output procedures.

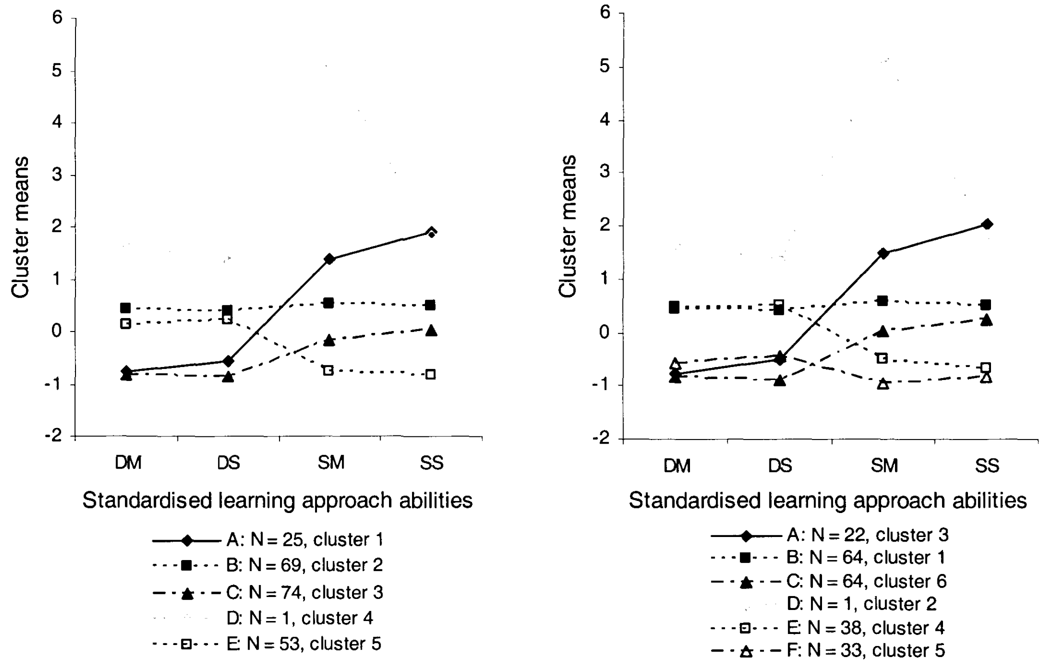
Figure 4.7: Comparison of item difficulty estimates for internal and external students on Learning scale

The DIF analysis (Figure 4.7) shows that deep items (uncoloured) were more easily endorsed by external students than by internal students. Conversely, surface items (grey) were more easily endorsed by internal students than by external students. These results support the findings reported above: that internal students reported taking a more surface/less deep approach to learning than the external students, while external students reported adopting a more deep/less surface approach to learning than the internal students. These differences point to the possibility of different relationships between deep and surface approaches in these two groups of students. This possibility was examined by separate cluster analyses of internal and external students' learning approach measures.

Cluster analysis

The *k*-means cluster analyses of internal and external students resulted in some relatively stable groups across five and six cluster solutions, which are reported in Figure 4.8 and Figure 4.9 below. Clusters with five or fewer members are coloured grey, and clusters are reordered into comparable identifiable groups to aid interpretation.

Results of the cluster analyses for internal students are shown in the form of two successive stable five and six cluster solutions (Figure 4.8a and b).



a: Five cluster solution

b: Six cluster solution

Figure 4.8: Five and six cluster solutions for deep motive (DM), deep strategy (DS), surface motive (SM) and surface strategy (SS) abilities: internal students

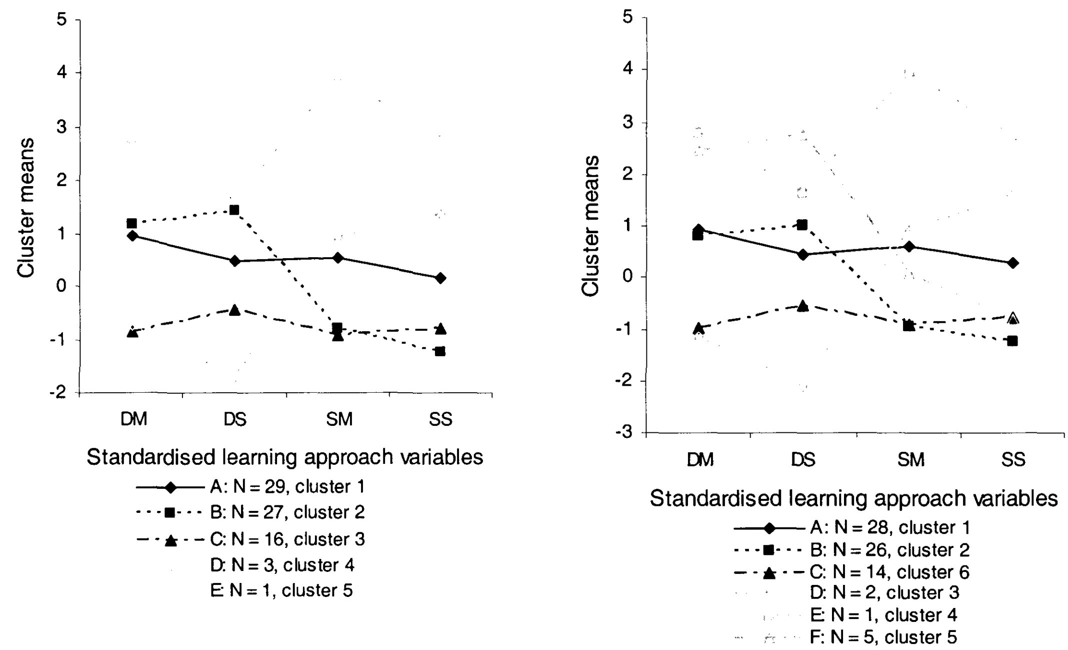
Three relatively stable major groups emerged from the five and six cluster solutions shown in Figure 4.8 a and b. These are:

- A (about 10% of cohort) with low deep and high surface cluster-means
- B (about 30% of cohort) with a flat profile of slightly above average deep and surface cluster-mean scores
- C (about 30% of cohort) with low deep and slightly below average surface cluster means.

A further group is common to both solutions; a single student (D) with extremely high scores on all approaches, especially surface motive.

Group E in the five cluster solution (about 25% of cohort) shows about average deep and low surface cluster-mean scores. This cluster is essentially redistributed into two in the six cluster solution. One of these groups (E – about 15% of cohort) has above average deep cluster-means, while the other (F – about 15% of cohort) has below average deep cluster-means. For internal students none of the solutions show groups with high deep and low surface cluster-means, with the closest to this being Group E, showing slightly above–average deep cluster-means together with low cluster-mean surface scores.

Results for the cluster analyses for external students are shown in Figure 4.9 a and b.



a: Five cluster solution

b: Six cluster solution

Figure 4.9: Five and six cluster solutions for deep motive (DM), deep strategy (DS), surface motive (SM) and surface strategy (SS) abilities: external students

Three major groups are quite stable across both solutions for external students shown in Figure 4.9. These are:

- A (about 40% of cohort) which has a more or less flat profile of moderately high deep together with slightly above average surface cluster-means
- B (about 35% of cohort), with high deep and low surface cluster means
- C (about 20% of cohort), with a flat profile of very low deep and surface cluster-means suggestive of little of either approach to learning.

For the external students, only two or three students are clustered into a group (D) with low deep and high surface cluster-means. Both solutions also show a single individual (E) with extremely high learning approach scores. The six cluster solution also identifies a small group of five students (F — about 7% of cohort) with very high deep and slightly below average surface cluster-mean scores.

In comparing the cluster analyses for internal and external students, both similarities and differences are apparent. The major similarity in patterns of learning approach variables is in the large groups of students in both cohorts with similar deep and surface cluster-means. The main contrast between enrolment types relates to the smaller groups exhibiting patterns of difference in deep and surface cluster-means. For internal students, no groups of students were detected with high deep and low surface cluster-means, whereas this combination of learning approaches is apparent in the external students. Conversely, although cluster analysis detected groups of internal students with low deep and high surface cluster-means, this pattern is not evident in external students.

In summary, this subsection has drawn results from a number of different analytic techniques which all point to differences in the learning approaches adopted by internal and external students. Mean deep approach scores are significantly higher for external than internal students, while mean surface approach scores are significantly lower. Rasch DIF analysis showed that external students, in general, found it easier to endorse deep items on the MSPQ than internal students. Results of *k*-means cluster analyses showed that while relatively large groups of internal and external students tended to have similar, mixed learning approaches, high deep and low surface approaches were not evident in groups of internal students but were in external students. Conversely, low deep and high surface approaches were evident in subgroups of internal students, but not in external students.

Although the preceding results show differences in learning approach adopted by the internal and external groups, these differences may not be attributable to the different enrolment contexts. As stated in Chapter 3, the external student sample differs from the internal students in age, as well as learning context. The effect of potentially confounding variables such as age and gender on learning approaches is therefore considered.

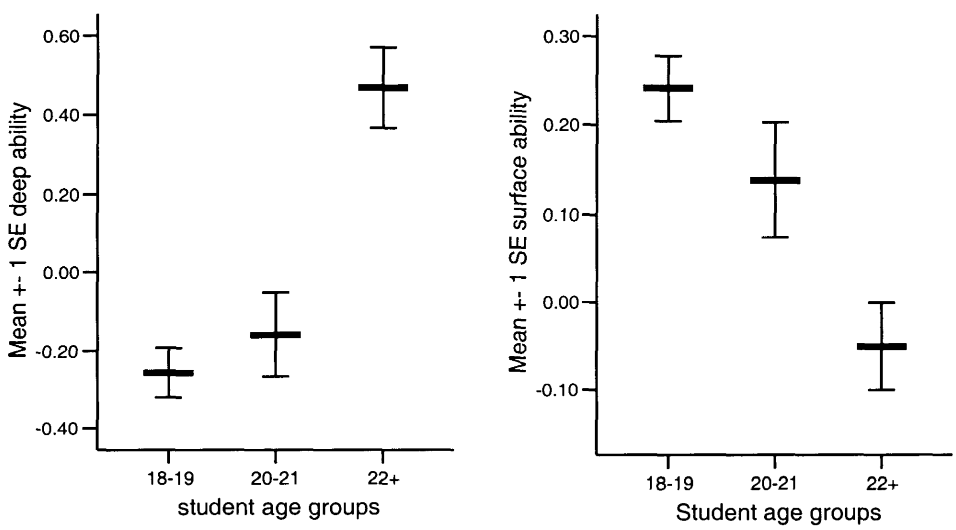
1b.v: Relationship between learning approaches, age, gender and enrolment type.

This subsection presents results pertaining to the relationship between age, gender, enrolment type and learning approaches. The findings of two–way between–groups ANOVAs are outlined, followed by a comparison of mean deep and surface learning approaches for three age groups. Finally, the age, gender and enrolment characteristics of the learning approach clusters are outlined.

Between–groups comparisons

The students were categorised into three age groups (18-19, 20-21 and over 22 years old) and two gender groups, as well as the two enrolment types. The impact of age and gender on the deep and surface approach ability scores established by the Rasch measurement model was explored, using two–way between–groups ANOVAs, as assumptions (including equality of variances) were met. There was a significant main effect for age on both deep [$F(2, 282 = 19.7, p < .001$] and surface [$F(2, 282 = 12.6, p < .001$] approach measures. The effect was large in the case of deep approaches (η^2 = 0.12), and moderate for surface approach measures (η^2 = 0.08). No significant effect was detected for gender or gender–age interaction.

The mean deep and surface scores for the three age groups are shown in Figure 4.10. Mean deep approach abilities across the three age groups are shown in Figure 4.10a, while surface mean abilities are shown in Figure 4.10b.



a: Deep approach ability   b: Surface approach ability

Figure 4.10: Mean deep and surface ability measures for three age groups

As shown in Figure 4.10 a and b, mean deep approach ability scores increase in sequentially older age groups, while surface approach ability means decline. In the case of deep approaches (Figure 4.10a), post–hoc comparisons using Tukey's HSD found that the mean deep approach ability for the 22+ age group (M = 0.46, SD = 0.97) is significantly higher than both the 18-19 group (M = -0.26, SD = 0.79) and the 20-21 group (M = -0.16, SD = 0.77). The two younger groups show no significant difference in deep approach ability measures. In the case of surface approaches (Figure 4.10b), the mean surface approach for the 22+ age group (M = -0.06, SD = 0.47) is significantly less than both the 18-19 group (M = 0.24, SD = 0.45) and the 20-21 group (M = 0.14, SD = 0.46). The two younger groups show no significant difference in surface approach ability measures. These results indicate that students 22 years old or more tended to adopt different learning approaches than their younger counterparts.

The impact of enrolment type on deep and surface ability scores could not reliably be separated using ANOVAs from the age effect, because of grossly unequal and in some cases very small group sizes. For example, only five external students are in the 18-19 year group, compared to 144 internal students. So while differences between learning approaches of internal and external students are clearly apparent, it is probable that these differences reflect to at least some extent co-varying differences in student ages in the two enrolment cohorts.

Characteristics of learning approach clusters

The cluster analyses described in a previous section of this chapter identified groups of students with different patterns of deep and surface approaches. These groups were identified across the whole sample (Figure 4.5), as well as within internal students (Figure 4.8) and external students (Figure 4.9). Here, the age and gender characteristics of these different groups are shown. For this purpose, the first (simpler) of the two successive solutions was selected from the three cluster analyses. For each of these groups, the gender, enrolment and age variables are summarised. These results are shown in Table 4.8.

Table 4.8: Cluster-mean scores for learning approach variables (all students, internal and external) with age and gender ratio

	Group	Cluster-mean scores: approach variables DM	DS	SM	SS	% of cohort	female: male	internal: external	mean age (years)
All students: 6 cluster solution	A	1.6	2.2	-0.2	-0.9	5	1.5 : 1	0.3 : 1	26.7
	B	0.3	0.4	-0.8	-1.0	22	1.4 : 1	1.5 : 1	25.1
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	D	-0.8	-0.8	-0.3	-0.1	31	1.2 : 1	7.5 : 1	20.9
	E	0.6	0.4	0.6	0.4	31	1.2 : 1	3.0 : 1	23.3
	F	-0.7	-0.7	1.3	1.8	10	1.4 : 1	9.0 : 1	21.7
	Values for valid cohort					**100**	**1.25 : 1**	**2.9 : 1**	**22.9**
Internal students: 5 cluster solution	A	-0.8	-0.6	1.4	1.9	11	1.4 : 1	-	20.2
	B	0.4	0.4	0.5	0.5	31	0.9 : 1	-	20.3
	C	-0.8	-0.9	-0.2	0.0	33	1.1 : 1	-	19.4
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	E	0.1	0.2	-0.7	-0.8	24	1.3 : 1	-	20.5
	Values for valid cohort					**100**	**1.1 : 1**	**-**	**20.1**
External students: 5 cluster solution	A	0.9	0.5	0.5	0.2	38	3.0 : 1	-	32.7
	B	1.2	1.4	-0.8	-1.2	36	1.7 : 1	-	31.0
	C	-0.9	-0.4	-0.9	-0.8	21	1.0 : 1	-	28.6
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	Values for valid cohort					**100**	**1.8 : 1**	**-**	**31.2**

Notes: clusters with five or fewer members are greyed to assist interpretation of major groups

The results in Table 4.8 show that, for the entire student cohort, the group with the highest deep approach cluster-means and relatively low surface approach mean scores (A) has the highest mean age, is predominantly external, and has a slightly higher ratio of females than for the entire cohort. Conversely, the group with the lowest deep cluster-means together with about average surface cluster-means (D) has the lowest mean age, is predominantly internal, and has a similar female to male ratio as the entire cohort.

In the case of the internal student groups shown in Table 4.8, age differences are very slight, but the groups with the lowest deep cluster-means (A & C) have the two lowest mean ages. The group with average deep and very low surface cluster-means (E) is the oldest. For external students, the group with the high deep and low surface cluster means (B) is intermediate in age between the other two major clusters, and the group with lowest scores on all variables (C) has the smallest mean age. Low scores on all approach variables also tended to be associated with younger students, whether internally or externally enrolled. These characteristics of the different groups identified in the cluster analysis are consistent with the previous results linking deep approaches to older external students, and more surface approaches to younger, internal students.

In summary, this subsection found that students aged 22 years or more had a significantly higher mean deep approach than those 21 or less. Conversely, the group older than 22 had significantly lower mean surface approach than the younger students. This suggests that the differences in learning approaches previously established between internal (mean age 20) and external students (mean age 30) are likely to be related to the age difference between these groups. Cluster analyses provided a similar message, with deeper approaches associated with older, externally enrolled students, and more surface approaches associated with younger, internally enrolled students.

Summary 1b

This section began by examining the reliability and validity of the instrument used to examine students' approaches to learning in the study context. Factor analyses provided reasonable support for the two constructs of deep and surface learning approaches, and reliability values were reasonable for the deep and surface scales, as well as for the entire MSPQ as a single scale. These findings were corroborated by the rating scale analyses conducted. The analyses indicated that all items and the three scales (single Learning scale plus deep and surface) conformed to the measurement model and supported the construct validity and reliability of the deep and surface scales, as well as the overarching Learning scale.

In addition to demonstrating acceptable reliability and validity of the MSPQ, the rating scale analysis of students' responses to the MSPQ generated a number of findings. Relative difficulties for each of the items were established, and students as a whole found it easier to endorse items about behaviours (strategy items) than those targeting attitudes (motive items). The student ability estimates of deep and surface approaches from the rating scales analysis of the entire Learning scale were adopted as the most appropriate measure of students' approaches to learning. There was no significant difference in the responses of Year 1 and 2 samples to the questionnaire.

In examining patterns of relationship between the two approaches to learning, deep and surface ability estimates were uncorrelated, indicating that the deep and surface constructs as operationalised in the MSPQ are independent approaches that students adopted during their learning in the study context. Banding of deep and surface ability measures defined five categories for each approach, with 40% of the students in a medium band for each of the deep and surface approaches, and fewer students in higher and lower ability bands. About one third of the sample were in the same ability band for deep and surface approaches, indicating widespread use of mixed approaches in their learning according to responses on the MSPQ.

Finer scale patterns of relationship between deep and surface approaches were investigated by cluster analyses. For the sample as a whole, most students were clustered into groups with relatively similar deep and surface cluster-means. This supports previous results in this section demonstrating an apparent trend for mixed approaches to learning in a large number of students. Smaller groups of students demonstrated patterns of learning approaches with either high deep and low surface cluster-means or, conversely, high surface and low deep cluster-means. This suggests that the students in those clusters adopted either a predominantly surface or deep approach to learning in the study context.

Differences were evident between responses of internal and external students to the MSPQ. The mean deep scale score for external students was significantly higher than for internal students, whereas their mean surface scale score was significantly lower than internal students. Rasch DIF analysis corroborated this finding, showing that items from the deep scale were more easily endorsed by external students, while items from the surface scale were more easily endorsed by internal students. Results from the cluster analysis refined these findings. A large proportion of both internal and external students seem to have adopted mixed deep and surface approaches. No groups with high deep and low surface cluster-means were identified for internal students, and only a minority of internal students belonged to clusters with low deep and high surface means. By contrast, in the case of external students, about 35% of the cohort belonged to clusters with relatively high deep means together with low surface means, and there were no clusters suggestive of low deep and high surface means.

The differences between internal and external student groups were examined with respect to possible confounding variables. Because external students were significantly older than internal students, student age was examined, together with gender. Students 22 years old or more had a significantly higher mean deep approach ability than those younger than 22, and a significantly lower surface approach ability. The differences in learning approaches identified for internal and external students undoubtedly reflect this age difference of the two cohorts. Characteristics of the groups of students identified in the cluster analyses are in accord with the other findings. Clusters demonstrating deeper approaches tend to comprise older, externally enrolled students, while those evidencing more surface approaches are predominantly internally enrolled, younger students.

The results in this section represent the nomothetic aspect of this investigation into the learning approaches theme. The findings are generalities based on analyses of students' responses to an instrument which evolved in large part from the cognitivist tradition. The next section presents complementary findings based on individual students' descriptions of how they went about their learning in the *Cellular and Organismal Reproduction* topic.

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

Information about learning approaches from the individual student interviews is presented in this section to provide richer, case–based information on learning approaches from the students' own perspectives. This line of inquiry was guided by the following research questions:

- 1c.i: Do the students express the theoretically predicted indicators of deep and surface learning approaches?
- 1c.ii: What were the learning approaches adopted in the study context by the interviewed students?

In this section, pseudonyms are used to conceal the identity of participants, with the chosen pseudonyms reflecting the sex of each participant.

1c.i: Indicators of learning approach

This subsection outlines the judgement criteria used to code the students' learning approach from the interview transcripts, to substantiate the coding decisions made. As outlined in Chapter 3, the coding process was based on the four *a priori* foci of the interviews, that is, learning motivation, intention, focus and strategies. Within each of these foci, some specific indicators of deep and surface approaches were hypothesised (see Chapter 3), based on strong theoretical foundations from previous studies. For example, motivation by intrinsic interest in the content is one indicator of a deep approach.

The interview transcripts provided strong evidence of these hypothesised indicators. The indicators were accordingly used as coding labels for assessing students' learning approaches. An explanation of the indicators for each of the foci using example extracts from interviews is provided in Table 4.9 to maximise the transparency of the final assessment of learning approach.

Table 4.9: Illustration of the meaning of labels used as decision criteria for establishing students' learning approaches from interview transcriptions

Interview focus	Indicative quotations from students	Indicators & likely approach	
Motivation (2° importance)	I find it very interesting. I mean anything to do with genetics I'm very interested in and I find it incredible, and just sort of amazing the way it all happens and everything	Intrinsic interest	D
	it was like sort of who cares?...Like I don't think of it as actually really ever happening. It's just what I have to learn	Intrumental/ Pragmatic	S
Intention (1° importance)	Understand it. Yes. Not learn it or memorise it, I want to understand it...When you're just, like, memorising something you don't understand what's happening and you don't understand why it's happening. Yeah. I want to understand it. And understand everything that's happening which makes a difference	Understanding	D
	Just get it all down pat...keep it fresh in your mind so it's there so you can produce it on the test.	Reproduction	S
Focus (1° importance)	when I come to the lecture I don't necessarily believe what they say. I like to think about it and compare it with what other opinions I've heard...What I have struggled with is the concept that inanimate matter can do that without guidance...	Meaning	D
	I just wrote down things I thought I'd forget and then read through the lecture and that's all...	Words or diagrams	S

Table 4.9 (cont.)

Memorising strategies (2° importance)	there's...an enormous clump of basic stuff, terminology, all this bullshit that you've got to learn...Often it's rote learning. If you write it out, if you talk it out, if you read it every day...So you've got to learn all these names, and OK, what's the difference between that and that...and then you can start to think: Oh alright, now I know why...	Repetition as an aid to understanding [1]	D
	I have great difficulty memorising anything unless I understand it first so I look for understanding first and then hopefully I'll remember it.	Memorising after understanding [1]	D
	Primarily, remember. With doing that you sort of, get a understanding, probably not a huge understanding, but yeah. It's more understanding but basically so you can remember information to reproduce in the test.	Memorising before understanding [1]	S
	I'm just learning it, like rote learning it and I'm not...understanding it. I don't necessarily really understand what I'm writing.	Memorising as rehearsal [1]	S

Note [1]: Forms of memorising using the terminology of Meyer and Shanahan (2003, p. 6).

The indicators outlined in Table 4.9 above were the basis of the coding process used in determining the learning approach adopted by each interviewed student. The indicative excerpts from the transcripts show what is meant by the indicators used in the coding, and to which approach they are linked. As is shown in the "Interview focus" column, some of the foci were given primary importance in coding decisions, and some were secondary. This was relevant in a few situations where conflicting indicators were expressed.

In summary, the coding labels defined in Table 4.9 were used in categorising the learning approaches of all the interviewed students. The results of this process are described in the following subsection.

1c.ii: Learning approaches adopted by the interviewed students

This subsection summarises the interview data on learning approaches of the sixteen individual interview participants. These students were categorised as adopting either deep, surface or mixed approaches, based on the approach indicators outlined in the preceding subsection. The reliability of the coding of interview transcriptions by interjudge agreement was high, with agreement on all but two cases relating to mixed approaches. One of the transcriptions which had been coded by the primary researcher as indicating mixed approaches was annotated by the second judge as "reproducing". Another student (Ruth) was coded as taking a surface approach by the primary researcher, but coded "reproducing – some understanding" by the second judge.

The summary data from the interviews are provided in three tables. Table 4.10 shows the students who were categorised as adopting a surface approach.

Table 4.10: Students describing a surface approach at interview, with transcript excerpts

Student	Some indicative transcript excerpts
Alex I# 19 yrs	S: Aiming to pass the test...I didn't really like doing Bio and all that because—they'll probably help me later on, but they're not what I wanted to actually do in life. I: So it's not really relevant to you? S: No...it might be later on when we get further into the course, but at the moment it means nothing pretty much I: Were you aiming to understand the stuff or remember it for the test? S: Remember it—and understand it if I could, but mainly remember it. Like usually when I go back through it you start to get what it's going on about, but in the lectures you don't really...I don't know. I just went through everything and what I remembered I remembered.
Amanda E# 21 yrs	S: I just want to get through the exam...well when I first learnt it, it was like sort of who cares? I often have to get...encouragement to make me realise that it is [relevant]...otherwise its just 2 separate things. Like I don't think of it as actually really ever happening. It's just what I have to learn...I just wrote down things I thought I'd forget and then read through the lecture and that's all...I'm just learning it, like rote learning it and I'm not...understanding it. I don't necessarily really understand what I'm writing.
Liam I 18 yrs	S: probably will be relevant for further units and things...apart from the exam at the end—no sort of current real usefulness... I: do you reckon you study to understand it or you study to remember it, primarily? S: Primarily, remember. With doing that you sort of, get a understanding, probably not a huge understanding, but yeah. It's more understanding but basically so you can remember information to reproduce in the test.
Kim I 18 yrs	S: I don't really know what I want to do when I'm finished but probably something along those lines so it's fairly relevant...I find all that interesting...Mmm I like all the DNA and genes and stuff... I: What were you aiming to do? S: Get better marks. Just revise it I suppose...refresh it in my memory so it's there and you think 'oh yeah' and you can remember it easier.
Jenni I 18 yrs	S: Relevant to the fact that I have to know it to pass, but probably oh, probably wouldn't use it very often.. :I: Why are you trying to remember rather than understand it given that? S: Cause it's quicker. And you're not asked to understand it. You're asked to replicate it... So if you remember how to replicate it, then you get the marks...
Tina I 18 yrs	S: this is the foundation work—it doesn't start to get specific to what I want the degree to be until next year. And so pretty much, most of it is pointless information, so just pass an exam and move on... I:And when you're reading through that what are you aiming to do? S: Just reading it. I: Why? S: Because it's that way I know what I missed in the lectures. I: So what are you trying to do with the stuff you missed? S: So read it once, it sticks in your head—you go down, then you've got the answers you need to do the test.
Charlie I 21 yrs	Not really relevant at all I suppose...I'm interested in the bigger picture not just the basic science behind it...it's just something that I just have to do...I find it really boring. It's like we're just being spoon-fed the material... I: are you aiming to understand the material or are you aiming to remember the material? S: Understand it. 'Cause if I understand it I'll remember it. Like I can, I can try to remember things and if I don't know what's going on I won't remember it.

Table 4.10 (cont.)

Ruth I 18 yrs	S: it's very relevant 'cause I want to do this sort of stuff...I'm more interested in stuff that I can't see...But because I've done it so much I didn't really pay that much attention... Because it's very repetitive... I: Were you trying to remember or understand it? S: Understand it. If I understand it I remember better...I understand what's going on and so –cos like I can picture it. Like I can picture the Krebs cycle happening—and so I understand it better. I can draw it and write it and stuff...I didn't study...I just looked over everything that we'd done in lectures and prac. Basically that's all I did...Because I figured it'd be asked basically only what we'd done in the pracs and tests. I: what were you trying to do? Remember something! No, I was just looking for stuff that I didn't know...I don't study...Like I'm not studying now...I put everything off until the day before usually...I'll study this stuff that I'm interested in more than I'll study the stuff that I'm not interested in. But like I'll only study for a test.

All of the students outlined in Table 4.10 were motivated by instrumental concerns, had an intention to reproduce rather than understand, focused at the level of words and diagrams, and their memorising strategies were predominantly memorising as rehearsal. Two students (Charlie and Ruth) described a form of memorising after understanding (theoretically indicative of a deep approach). This understanding, though, seemed to be sought not for its own sake, but simply as a trigger to remember enough content to reproduce in the practical test (intention indicative of a surface approach). Ruth's approach in particular was difficult to assess. She seemed to have a frustrated intrinsic interest in the material, which was not translated into a deep approach. This was a case where there was some conflict between the indicators, but based on the primary importance ascribed to focus and intention in the decision criteria, she was categorised as adopting a surface approach.

Two of the students described their learning in a way consistent with a mixed approach. The comments of these two students are outlined in Table 4.11.

Table 4.11: Students describing a mixed approach at interview, with transcript excerpts

Student	Some indicative transcript excerpts
Tom I 19 yrs	I: What were you aiming to do? S: Probably just get a broader idea and keep it in my head. But how everything that we were going to cover for the prac test. 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. I: You were talking about understanding material, before you were talking about getting stuff in your head so that you can produce it on the exam. Which is more important or are they both the same? S: Oh they both relate to each other. So you've got to understand the information to like put

Table 4.11 (cont.)

Tom (cont.)	it down on the paper...to understand it you've got to know how to write it and produce in the test form... I:Do you do much extra reading or thinking about this sort of stuff other than when you're studying for a prac test ? S: Not really. I may – if something's really interesting then I'll look it up or something like that but normally I probably wouldn't unless stuff in the test...
Ryan I 20 yrs	I: what were you aiming to do when you were studying? S: Just to do alright in that, you know for the test. It's worth about 10% of the marks... I: were you aiming to understand the material, or remember it for the prac. test or what? S: A bit of both....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. I: And why did you want to know what was going on? S: I just did, yeah, just found it interesting...There's not much point in understanding something if you don't remember it...Understanding should help you remember.

The excerpts summarised in Table 4.11 indicate that Tom and Ryan showed a mix of the indicators of deep and surface approaches. Tom had an instrumental motivation, intended to reproduce and understand, seemed to focus on both the words and the meaning, and showed dissonant strategies of memorising before and after understanding. Ryan was motivated by both instrumental concerns and intrinsic interest, aimed to both remember and understand, focused at the level of words and diagrams and used a form of memorising after understanding. They were both therefore categorised as showing mixed approaches to learning.

The final group of students was categorised as using a deep approach in their study. The results for this group are outlined in Table 4.12.

Table 4.12: Students describing a deep approach at interview, with transcript excerpts

Student	Some indicative transcript excerpts
Adam E 35 yrs	it gives you a understanding of life, the way things reproduce, the way that people reproduce ...It just gives you a greater understanding of everything around you and that's why I get a lot more out of it... I: Are you aiming to understand primarily or to remember? S: Well I think the 2 go hand in hand and I think if you understand you will remember...[re reading,taking notes & summarising study guide]...because that's the way I tend to retain things .3-4 pages of things that I sort of understood but probably would have helped me in the exam.
Laura I 19 yrs	I don't see any relevance to what it has to do with anything that I'm studying, you know. I mean I want to do genetics and things, so it's probably important but...Mm, I didn't hate it but it was a bit...it was OK... I: what are you aiming to do with that stuff? S: Understand it. Yes. Not learn it or memorise it, I want to understand it...When you're just, like, memorising something you don't understand what's happening and you don't understand why it's happening. Yeah. I want to understand it. And understand everything that's happening which makes a difference...You don't just memorise answers or memorise what to write.

Table 4.12 (cont.)

Jacinta E 58 yrs	I wanted to know what they expected us to know…I'm doing this stuff so I can do Plant Taxonomy because I'm doing Archaeology so the short answer's "no". I really don't think they [the stages] are relevant…My view about it all was "boring" and "why do we have to have it" but after realising…I can see a botanist's point of view… I: When you're talking about the rote-learning...are you aiming to remember it or are you aiming to understand it? S: First of all it's to remember all the words and then what I try to do is put it all together and then I will worry it until it makes sense…You had to know the words so you could think about them…you see having done science…there's what I call an enormous clump of basic stuff, terminology, all this bullshit that you've got to learn…Often it's rote learning. If you write it out, if you talk it out, if you read it every day…So you've got to learn all these names, and OK, what's the difference between that and that...and then you can start to think: Oh alright, now I know why...
Rob E 33 yrs	S: That in particular isn't necessarily interesting to me but the whole unit, and that's part of it, is very interesting. It's just part of a whole to me…It is fascinating stuff. It's just mind–boggling… I: When you were studying…were you aiming to remember the material or to understand it? S: Uh, understand it really. I have great difficulty memorising anything unless I understand it first so I look for understanding first and then hopefully I'll remember it…when I come to the lecture I don't necessarily believe what they say. I like to think about it and compare it with what other opinions I've heard…What I have struggled with is the concept that inanimate matter can do that without guidance…yet the stuff happens by itself inside the cells every day…I keep a notebook & I write down things that I think are important or interesting and worth noting and also I do diagrams.
Kirsty I 19 yrs	S: I like to sort of look at—I'd like to eventually go on and do Vet. Science and I sort of look at some vet books about—you know is it the same in all the animals? What chromosome numbers do other animals have and stuff like that. There's extra meaning about it…I find it incredible, and just sort of amazing the way it all happens and everything and, um. Yeah I really did find it very interesting…I figure that's there's not much point in just remembering it. Um I mean you can just sort of regurgitate it all a bit but there's not much point in that? …I like to be able to get it right and understand why is that happening, not, this is how it happens, that's just the way it is. I like to go, "why is it that way?" and question it a lot, so I like to be able understand it.

The excerpts for all of the students in Table 4.12 show an intention to understand and a focus on the meaning of the content. Three of these students (Adam, Rob and Kirsty) were motivated by intrinsic interest in the subject matter. Jacinta and Laura, though, sought meaning, intended to understand and used strategies consistent with a deep approach although they found the subject matter boring and/or irrelevant. Jacinta's strategy of repetition as an aid to understanding is entirely consistent with the deep approach indicators used in the judgement criteria, despite her reference to rote-learning. An additional external student (Paul) described a strongly deep approach at interview, but later tape malfunction meant that it could not be transcribed and coded in the same way as the other students.

A comparison of the approaches of internal and external students from the interviews shows some apparent differences. Three of the four external students reported a deep approach to their study, and these students were all considerably older than the rest of the students. Seven of the eleven internal students reported a surface approach to their learning. Although the number of students involved is relatively small, these findings suggest an association between deep approaches and older/external students, and surface approaches and younger/internal students.

In summary, this subsection has detailed the learning approaches adopted by the interviewed students, using the indicators previously described. Surface, deep and mixed approaches were identified, with some differences emerging between internal and external students.

Summary 1c

The interviews provided a range of rich description and information on students' learning approaches. The interview transcripts detailed the students' learning motivation, intention, focus and strategies, which were used to code their learning approaches as predominantly deep, surface or mixed.

Eight students reported adopting a surface approach in their study of the relevant section of the unit, with another two students showing indications of a mixed approach combining mixed intentions and associated dissonant forms of memorising. Five students described their study behaviours and attitudes in ways that were clearly consistent with a deep approach. These results also indicate that some students who adopted a deep approach in their study did so despite reporting instrumental motivation. By contrast, no students using strategies typical of a surface approach were intrinsically interested in the subject matter. Finally, three of the four external students reported a deep approach to their study, while seven of the eleven internal students reported adopting a surface approach to their learning. This is suggestive of an association between deep approaches and external students, and surface approaches and internal students.

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

This section compares the quantitative and qualitative assessments of learning approaches described in previous sections of this chapter. These data were compared to check the extent to which they corroborated each other, as a check of the validity of both the quantitative and qualitative findings previously presented.

The comparison of results is shown in a summary form in Table 4.13. This shows the coding labels from the interview analyses, the deep and surface ability estimates from the MSPQ responses, and the deep and surface ability bands of the learning approach ability estimates.

Table 4.13: Learning approaches of students from analysis of interview transcriptions, together with deep and surface ability measures and bands from the MSPQ

Student	Enrolment	Age (yrs)	Learning Approach from interview	Learning Approach from MSPQ	Learning approach "ability" estimates from MSPQ			
					Deep ability estimate	Deep ability band	Surface ability estimate	Surface ability band
Alex	I#	19	Surface	Surface	.29	medium	.42	high
Amanda	E#	21	Surface	Mixed	.87	high	.49	high
Liam	I	18	Surface	Surface	.01	medium	.63	high
Kim	I	18	Surface	Surface	-.76	low	.29	medium
Jenni	I	18	Surface	Surface	-.47	medium	.56	high
Tina *	I	18	Surface	N/A	N/A	N/A	.29	medium
Charlie#	I	21	Surface	N/A	N/A	N/A	N/A	N/A
Ruth	I	18	Surface	Neither	-.56	low	-.97	v. low
Tom	I	19	Mixed	Deep-mixed	1.18	v. high	.42	high
Ryan	I	20	Mixed	Surface	-.76	low	.16	medium
Adam	E	35	Deep	Deep	2.34	v. high	-.15	low
Laura	I	19	Deep	Surface	-1.07	low	.35	medium
Jacinta	E	58	Deep	Deep	1.40	high	-.47	low
Rob	E	33	Deep	Deep	-.18	medium	-.21	low
Kirsty	I	19	Deep	Deep	.97	high	-.21	low
Paul ^	E	44	(Deep)	Deep	3.73	high	-0.55	low

Notes:

No valid data were available for Tina's response to the deep scale of the MSPQ.
#No ability measures were available for Charlie as he did not respond to the MSPQ.
^Paul's responses to the relevant questions could not be transcribed because of tape malfunction, but he expressed a strongly deep approach to learning in his interview.

In eight of the thirteen cases with all available data, there is congruence between the results of the interviews and the quantitative data (Table 4.13). In these eight cases, students who were classified from interview as adopting either deep or surface approaches were in a higher ability band for that particular approach. For example, from his interview Alex was coded as reporting a surface approach to his learning, and his ability estimates are high in the surface ability band, and only medium in the deep band.

There are, though, five cases where the quantitative and qualitative assessments of learning approaches are not in agreement. Four of these cases involved students reporting mixed approaches to learning in either interview or the MSPQ. In two of these cases (Ruth and Amanda) the interview analyses resulted in a coding for one predominant approach to learning (either surface or deep), but the quantitative data did not reveal a single predominant approach. For example, Amanda's interview indicated a surface approach to learning, but her MSPQ ability measures were high on both surface and deep approaches. While Ruth's surface ability measure was higher than the deep, both were so low that her MSPQ responses essentially reflected use of mixed or neither approaches to learning. Signs of this were in her interview transcript, which had been coded by the independent judge as "reproducing, some understanding", although she had been categorised as adopting a surface approach. In two cases (Ryan and Tom), the interview suggested mixed approaches to learning, but MSPQ responses indicated more use of surface or deep approaches.

In only one case (Laura) does the quantitative data (suggesting a predominantly surface approach) directly contradict the qualitative analysis (suggestive of a deep approach). Laura was asked in her interview whether she had filled in the questionnaire properly, but her answer was slightly equivocal:

> I: Now, with the questionnaire, [...] did you fill it in properly or did you sort of...?
> S: I think I did it fast.

Laura's interview, interestingly, also revealed an extremely strong achieving aspect to her study that was not evident in any of the other interviewed students:

> I: So how come you're so organised?
> S: I stress out if I'm not organised, if I don't know what's happening.
> I: What worries you?
> S: I don't know, I don't know, I just, um, just like to know everything that's happening and not forget anything. Be organised and do my best. It's a bit of a worry because it's not always good.
> I: Why isn't it good?
> S: You get too stressed and you can get sick and your hair falls out. My hair's fallen out before [laughs ruefully]
> I: Oh really?
> S: Yeah, Year 12.
> I: Was that just last year for you?
> S: Yeah and I had glandular fever and there's...I don't even see the importance of doing it half the time.
> I: So you really feel the need to perform, to do well?

S: Yeah, and I don't have any pressure from my family or anyone else to do that it's just all myself.
I: And how did you go in first semester?
S: Well, yeah, I got a distinction average, so that was good.
I: Does that mean that you feel pressured to repeat that? Does it add to the stress levels?
S: Yeah, It does a bit. Because I did maths in year 12 so doing maths last semester was easy so that bumped my mark up. I don't have that this semester, so I'll see how I go but...as long as I do well I suppose...
I: Somebody...was talking about some student that got an HD in an assignment, and that student was really stressing out after that, and she said it's like buying a new car—and being scared of scratching it—it's the same, sort of...
S: Yeah, well I came third in my degree, Rural Science, equal third and I'm a bit worried, like I want to stay up there for the rest of the degree so when I finish I'm still up there. So that makes it hard, because I think everyone else will be studying harder, because they didn't necessarily go as well as they thought they were going to so they're going to be working harder this semester or whatever, might be a bit more competition I think.

Laura's very strong achieving approach may have interacted with her expression of deep and surface motives and strategies in either the interview or the MSPQ.

Summary 1d

With the exception of Laura, the results of the quantitative and qualitative data presented in this section are reasonably consistent. Most students whose responses to the MSPQ suggested a predominantly deep or surface approach expressed using that approach at interview. Four out of the five cases of non-agreement between interview and MSPQ responses involved students whose responses indicated mixed approaches to learning. These results also highlight the complementarity of the nomothetic and idiographic methods used to determine the learning approaches of the participating students.

Overview

This chapter has outlined the results pertaining to theme 1 of this study, which relates to students' approaches to learning in the study context. The first line of inquiry that was posed in this chapter (1a) related to the characteristics of the study context underlying the approaches adopted. For internal students, the context was essentially teacher–centred lectures and illustrative practicals, and the external students experienced similar but more intensive teaching during a residential school, complemented by printed topic materials which were studied at home. Perceptions of the students to these contexts were outlined, with both similarities and differences apparent between perceptions of internal and external students.

The second line of inquiry in this chapter (1b) focused on students' responses to the MSPQ. It was found that the instrument was reliable and valid in the study context, and that deep and surface measures were independent of each other. Many of the responses to the MSPQ indicated relatively evenly mixed approaches to learning, with some smaller groups of students reporting predominantly deep or surface approaches. The external, mature–aged cohort reported more use of deep approaches and less use of surface approaches than their internal, younger peers.

The third line of inquiry (1c) was an investigation of students' descriptions of their learning approaches during interviews. Most of the students described their learning in a way consistent with either a deep or surface approach, with surface approaches predominating in the internal group and deep approaches more frequent in the external group. Two of the students described their learning in a way indicative of mixed approaches.

The final aspect of this study theme (1d), was an exploration of the relationship between quantitative and qualitative assessments of learning approach. It was found that the two types of data yielded generally consistent and complementary findings.

Within this chapter the findings relating to the first of the themes of this study have been presented. The following chapter outlines the results of the second study theme of learning outcomes.

Chapter 5

Results: Learning outcomes

Introduction

The previous chapter focused on the first of the research themes, relating to the learning approaches adopted by students in a specific study context. This chapter presents the students' learning outcomes from that context, which is the focus of research theme 2. The three lines of inquiry framing this aspect of the research which were posed in Chapter 2 are:

2a: What are the categories of written responses to a specific question on a concept central to the study context, and do they fit with the SOLO model?

2b: What is the distribution of SOLO categories across the sample?

2c: What are the SOLO categories of students' verbal explanations of the same question in interviews?

2d: What is the relationship (if any) between the SOLO categories obtained for the written and verbal explanations of the target question?

The results pertaining to these lines of inquiry are presented in the order they are posed above. Results pertaining to 2a are predominantly a qualitative analysis of 575 written responses to meiosis questions in practical tests and end-of-semester examinations, which were obtained from 334 students over both years of the study. The results of this analysis are then interpreted in terms of the SOLO model. The distribution of the SOLO categories obtained from the written responses across the sample is then described (2b). Verbal explanations of meiosis from interviews with sixteen students are then described and interpreted (2c), according to the SOLO categorisation that had been obtained from analysis of the written responses. Finally, the relationship between students' written and verbal explanations of meiosis (2d) is outlined.

2a: Students' written responses to meiosis questions

This section presents the results of the analyses of students' responses to written meiosis questions, which were within the usual assessment regime of the unit. These questions were:

1. Describe your understanding of the process of meiosis as fully as you can. (Practical test)
2. Describe in full the process of meiosis, and why it is so important in the life cycle of plants and animals (Examination – first part of question analysed)

This line of inquiry was directed by the following three research questions:

2a.i: What are the different categories of responses to the meiosis questions?

2a.ii: Do the categories of response fit with the two-learning-cycle SOLO model?

2a.iii: How valid is the SOLO model as a measure of learning quality in the specific study context?

These questions are used as the organising principle for this section.

2a.i: Categories of responses to meiosis questions

This subsection presents the results of the initial step in the analysis of the written responses, which involved an iterative process of categorising responses based on patterns of similarity and difference. Some aspects of the analysis are described, followed by an outline of the categorisation achieved, and a grouping of categories is then presented.

Issues in categorisation

Coding responses required thorough understanding of all the related scientific concepts and terms, in order to detect qualitative differences in responses. In many responses, terms were used inappropriately and in the wrong context; and in some cases terms were used ambiguously. In the grouping of responses, therefore, the mere mention of a term was treated differently to situations where the term was used in context, and as part of a detailed description of a process. For example, there is a qualitative difference between a response that states that "homologues are separated" and a response that shows what homologues are, how they interact and how and when they separate. Although both these examples mention homologues, they could well be placed in different categories reflecting the overall difference in response quality.

Similarly, many responses were set out as a series of steps, indicated by bulleted or numbered points, diagrammatical points or diagrams linked by arrows. Some responses used paragraph format, with or without step–like diagrams. Whether responses were set out in point form or not bore no apparent relation to the quality of the response. This is unsurprising as the notion of different sequential steps is central to the process of meiosis, and to descriptions and explanations of it, for example in the students' textbook (Campbell & Reece, 1999). Therefore, while some descriptions of SOLO levels (e.g., Biggs & Collis, 1982, p. 25) describe point format as characteristic of multistructural responses, the analysis of categories of responses in this study did not attach any significance to whether responses were presented as a series of points or as a paragraph. The relevant points and how well they were integrated into a "coherent whole" in this case were not necessarily linked to the physical format of presentation, because of the nature of the concept being investigated.

After adding and collapsing emerging sub-categories a final scheme emerged which most clearly reflected the different groups of like responses in a manageable number of 11 categories. These categories of responses are described in more detail below.

Categories of response

This categorisation is a descriptive account of the similarities and differences between identified groups of responses, based on different elements of meiosis expressed in the responses.

Category 1

In these responses the relevant practical test question or examination question were blank, so the category essentially contains non-responses to the items.

Category 2

These responses focus on only one component of meiosis, the element of *sequence* or *process*. Responses contain no written description of other aspects of meiosis such as the biological structures or activities involved, the products of meiosis, or its consequences. The inclusion of the term "meiosis" in the list that comprises the sample response shows incoherence between phase sequence and the overall concept of meiosis.

Sample response 2:

> Interphase 1
> Prophase 1
> Anaphase 1
> Telophase 1
> meiosis
> Interphase
> Prophase
> Anaphase
> Telophase
> Cytokinesis

Category 3

These responses incorporate some of the features of entities, process, sequence, product and consequence of meiosis, but these elements are not expressed in a coherent form because of the conflation of meiosis with other biological processes such as fertilisation and/or mitosis, confused hierarchy of relevant entities involved, and misuse of terminology.

Sample response 3:

> Meiosis is important in the lifecycle of plants & animals as it is the creation of new cells that are the same as parent cells. The process of meiosis involves the dividing of 2 cells, and regrouping to form new cells, the end result is sister chromatids.
> In plants it goes:
> G1
> S
> G2
> Interphase 1
> Prophase 1
> Anaphase 1
> Telophase 1
> Interphase II
> Prophase II
> Anaphase II
> Telophase II
> Cytokinesis

Category 4

These responses provide a description of meiosis that coherently relates some of the features of meiosis to state that meiosis is a cell division resulting in daughter cells different from the parent. Although the responses integrate elements of meiosis into a coherent basic explanation of the concept, they still show conflation of meiosis with fertilisation (as in the sample response) or with mitosis. Meiosis has not been clearly delineated from related concepts.

Sample response 4:

> Meiosis is the process of cell division that results in 4 genetically different daughter cells (compared to that of their parent).
> The process involves the 2 parent gametes (haploid)(n) joining to form a zygote which is diploid (2n).
> The process involve Meiosis I with Interphase I, Prophase I, Metaphase I, Anaphase I, & Telophase I the cytokinesis (the separation of 2 cells). The process is repeated in meiosis II with similar steps resulting in the 4 diploid (n) genetically different cells compared to the parents.

Category 5

These responses coherently integrate some core aspects of meiosis into an uncontradicted description of meiosis as a reduction division resulting in X daughter cells. The responses may show some inaccuracies of content (i.e., that the haploid products are 2 in number, and identical). Essentially in Category 5 meiosis is crystallized as a discrete unit of information, delineated from other concepts. The responses do not describe the activities of chromosomes at substages/phases of meiosis, though may state that these phases exist.

Sample Response 5:

> Meiosis is the creation of sex cells – rather than a cell with a full complement of chromosomes regenerating (diploid) meiosis involves a cell with only one of each chromosome (haploid). Meiosis occurs in two stages – Meiosis 1 & 2, and each of these is made up of 5 phases – interphase, prophase, metaphase, anaphase & telophase –(meiosis creates two identical daughter cells).

Category 6

The responses in this and subsequent categories describe, if only briefly, the sequential activities of chromosomes in meiosis. The responses are engaged with the subprocesses of meiosis and how these contribute to the resulting products. Less sophisticated responses in this category make only scant description of a limited number of activities such as chromosomes replicating, splitting or moving in the different phases/stages. Some responses indicate that there are two rounds of mitotic–like division, and describe them without going into detail of activities at specific phases. More sophisticated responses trace most of the chromosomal activities, but no responses describe coherently the different activities in the two different rounds, that is, replication and separation of chromosomes in the first round and separation of chromatids in the second. Consequently, the processes that result in formation of 4 n cells are not adequately or completely related. Although the term homologues occurs in some responses, it is not integrated into a sequential discussion of the chromosomal activities.

Three examples of responses in this category are provided below to indicate the range of responses it contains.

Sample Response 6a:

> - Meiosis is the reduction of diploid (2n) to haploid cells (n)
> - End product is 4 haploid (n) cells
> - Can be broken up into 2 sections: meiosis I and meiosis II
> - Meiosis I is the separation of homologous chromosomes. It has the phases prophase, metaphase, anaphase, telophase and cytokinesis.
> - Meiosis II is the separation of sister chromatids. This process is similar to mitosis.
> - The purpose of meiosis is to produce gametes/sex cells which are haploid in number.

Sample response 6b:

> Meiosis is the process that produces sex cells. Meiosis is needed in reproduction because it divides up the number of chromosomes present in the parent cell, to make 4 cells with half a chromosome pair in each. Firstly it goes through the same steps of mitosis in Stage I: Interphase, prophase, Metaphase, Anaphase, Telophase. It then goes through Stage II, where the same phases are used but the chromosomes of the 2 cells from I are split to make 4 with ½ chromosome pair in each.

Sample response 6c:

> Meiosis is essentially made up of 5 stages, 4 of these repeat themselves. Meiosis is important due to the fact that it decreases the number of chromosomes in a cell by half. If this did not happen, every time a new embryo/zygote is formed it would have double the amount of chromosomes as each of its parents had.
> Stages: Interphase – tightly enclosed chromosomes, entangled.
> Prophase: chromosomes separate, still remaining joined
> Metaphase: chromosomes line up on the metaphase plate
> Anaphase: spindles form at each pole of the cell and pull apart the chromatids
> Telophase: cell separates into two cells, each with the same chromosomes (identical daughter cells) REPEATS.

Category 7

These responses provide descriptions of the chromosomal activities in meiosis, organised by phases or stages, in explanations of how these activities and subprocesses result in 4 haploid gametes. They are slightly incomplete or contain minor erroneous statements about when chromosomes and chromatids separate, or when DNA replicates, which weakens the coherence of the explanation of how 4 n cells are formed. The descriptions do not contain any or adequate description of the role of separation of homologues. Where homologous pairs are mentioned, the expression of the concept is confused.

Sample Response 7:

> Meiosis has 2 phases Meiosis I and Meiosis II each containing 5 subphases
> Meiosis I
> Interphase: large dark nuclei
> Prophase chromosomes appear tangled but are visible
> Metaphase I: chromosomes aligned along equator
> Anaphase I chromatids pulled to opposite spindle poles – shaped like V.
> Telophase I chromosomes dark mass at each pole of cell – 2 cells formed
> Meiosis II
> Prophase II – chromosomes replicate
> Metaphase II - chromosomes align along the equator
> Anaphase II – chromatids pulled to each end of spindle poles
> Cytokinesis – formation of 4 cells, cytokinesis is division of cytoplasm
> Meiosis from diploid to haploid. Occurs only in organisms that reproduce sexually. Meiosis produces gametes of humans – results in half the chromosome number – haploid.

Category 8

Like Category 7, these responses integrate detailed descriptions of the activities of DNA replication, separation of chromosomes in the first stage of meiosis (MI) and chromatids at the second stage (MII) to provide a good explanation of how 4 n cells are formed. The difference between this category and category 7 lies in the coherence of the explanations. No misconceptions or areas of confusion in this category weaken the coherence and integrity of the explanation of how 4 n cells are formed, although this structural coherence does not apply to the role of homologues. The responses do not incorporate the role of separation of homologues, and if homologues are mentioned at all it was in an incoherent form.

Sample Response 8:

> Meiosis is the division of a diploid set of chromosomes resulting in 4 haploid chromosomes. Meiosis can be divided into 2 stages. Meiosis I and Meiosis II. Each of these stages have prophase, metaphase, anaphase, telophase and cytokinesis.
> In meiosis I:
> Start out with a diploid cell with 2 chromosomes (with sister chromatids)
> ⇨ In prophase, sister chromatids are condensed, and crossing over occurs during synapsis, and spindles connect to centrome of chromosomes
> ⇨In metaphase, the two replicated chromosomes line up on the metaphase

plate
⇨In anaphase the 2 replicated chromosomes are pulled apart by spindles to opposite poles of the cell
⇨In telophase a new cell wall begins to form (in plants) or (in animals) a pinched furrow
⇨In cytokinesis, division of the cytoplasm occurs and 2 new cells are formed
⇨In meiosis II:
⇨Prophase – 2 haploid cells, spindles
⇨Metaphase - Replicated chromosome line up on the metaphase plate
⇨Anaphase, sister chromatids are pulled towards opposite poles of the cell, by spindles
⇨In telophase, chromatids in opposite ends of each cell. Furrow/cell plate (wall) begins to form
⇨In cytokinesis, division of the cytoplasm occurs
⇨Result of meiosis is 4 haploid daughter cells.

Category 9

As in Category 8, these responses integrate the chromosome activities at different stages or phases. Some of the responses abbreviate the second stage to "like mitosis" or "the same as meiosis I except that…" instead of rewriting all the phases again. Significantly, responses in this category mention the separation of homologous pairs in MI, and there is no indication of misconceptions about the nature of homologous pairs. However, these responses do not describe the crossing over of homologous chromosomes. They may mention that crossing over occurs (like many other responses at lower levels) but do not explicitly recognise the fact that it is the homologues that cross over.

Sample response 9:

There are two stages in the process:
Meiosis I:
Interphase I: DNA replication occurs with chromosomes acquiring two identical sister chromatids joined by the centromere
Prophase I: Chromosomes untangle and become visible. Homologous chromosomes pair up along side one another.
Metaphase I: Chromosomes attach to spindle fibres along the cells center via their centromeres.
Anaphase I: Homologous chromosomes separate and are pulled to opposite poles by spindle fibres
Telophase I: nuclear membrane reforms, creating two haploid cells.

Meiosis II:
Prophase II: chromosomes untangle and become visible. A new spindle forms.
Metaphase II: chromosomes realign along cell's center and attach to spindle fibres by their centromeres.

> Anaphase II: Chromatids on each chromosome separates and are pulled to opposite poles by spindle fibers.
> Telophase II: Nuclear membrane reforms, chromosomes become thin again, spindle disappears.
> Cytokinesis: Cytoplasm divides creating 4 separate haploid daughter cells.

Category 10

Like Category 9, these responses integrate the chromosome activities at different phases or stages, into an explanation of how 4 n cells are formed, and recognise the separation of homologues at MI. Phase/stage names are usually used to organise the discussion, or otherwise detailed custom diagrams. As an advance on Category 9, these responses explicitly incorporate the crossing over of homologous chromosomes at MI into the explanation of meiosis.

Sample response 10a:

> Meiosis is the process in sexual reproduction whereby the chromosome numbers are halved to form gametes that will then fuse with gametes from [a] different individual to produce a single cell. Zygote.
> Diploid cell 2n →meiosis→ Haploid n
> Meiosis starts with duplication of chromosomes . meiosis consists of two nuclear divisions.
> Meiosis I: The duplicated chromatids line up in tetrads or pairs of homologous chromosomes. There is genetic recombination at this point. The homologous chromosomes then separate into 2 separate cells. Ploidy = n.
> Meiosis II: Separation of sister chromatids that results in 4 haploid cells all genetically different from each other and the parent cell.

Sample response 10b:

> Meiosis involves the production of haploid cells necessary in sexual reproduction. Two phases of meiosis occur – during the first phase, the homologous chromosomes separate, and during Meiosis II sister chromatids separate as in mitosis.
> Interphase is the longest phase of Meiosis I, involving duplication of DNA. Prophase sees the process of synapsis, whereby homologous chromosomes form tetrads and crossing over occurs. Metaphase aligns homologous chromosomes on the metaphase plate with one member of each pair facing opposite poles of the cell. Anaphase separates homologous chromosomes to opposite poles, and telophase sees the reforming of the nuclear membrane, and 2 haploid cells are produced.
> Meiosis II does not have an interphase involving replication. There sister chromatids are aligned and separated as in Mitosis, with the 2 haploid cells giving rise to 4 haploid gametes, genetically different from each other and the parent cells. Meiosis produces variation in gametes, necessary for adaptive evolutionary change. This occurs via crossing over, independent assortment and random mating.

Category 11

The responses go another step beyond Categories 9 and 10, explicitly mentioning independent assortment of homologues as well as the crossing over of homologous chromosomes as contributing to genetic diversity.

Sample response 11:

> In meiosis, chromosomes in a diploid (2n) cell duplicate (as in a) [this refers to the answer to the previous sub-question about the cell cycle]. Each pair then joins with the other sister chromosome pair in the cell with genetic coding for similar traits to form tetrads. Meiosis consists of two divisions. In meiosis I, homologous pairs are divided out of the tetrad (causing genetic variability due to randomness of which daughter cell each pair goes to, and also due to "crossing over" which causes part of one chromosome to be "swapped" with the same part of the chromosome it was joined to. The cell then undergoes cytokinesis to produce two cells. Meiosis II then occurs, similar to mitosis, the pairs of chromosomes line up on the metaphase plate and are separated by the mitotic spindle pulling them apart. Again this is followed by cytokinesis, giving a total of four genetically different cells. Meiosis is important because it promotes genetic variation. Meiosis gives rise to 4 haploid (gametes or spores) cells which then randomly join (fertilisation) giving millions of possible genetic combinations for the resulting organism.

Grouping of categories

Once these individual categories were established, the characteristics of the categories were examined further for broader similarities. A key focus was for patterns in degree of abstraction of responses and structural complexity that might relate to the two-learning-cycle–per-mode version of SOLO outlined in Chapter 2. The resulting grouping of categories is shown in Table 5.1 below.

Of the three groups of responses in Table 5.1, Group B focuses on what meiosis is, with much less emphasis on how it occurs. Responses in Group C explain to varying extents the mechanisms generating the products of meiosis. Finally, Group D responses incorporate discussion at the more abstract and complex level of homologues, to explain the genetic diversity and genomic integrity of the meiotic products.

Table 5.1: Summary grouping of categories of response to meiosis questions

Cat. #	Group	Group description
1	A	Non-responses
2 3 4	B	Something is known about meiosis (e.g., involved in reproduction, some constituent structures/processes), however knowledge is fragmentary and the relationship of meiosis to other concepts is often fuzzy, for example, meiosis is merged with or comprises fertilization or mitosis. Irrelevant information and inappropriate terminology is therefore often included. Although responses may state **what** meiosis does, chromosomal activities are usually not used in explanatory way to convey how meiosis works.
5 6 7 8	C	The major point of departure for this group is that meiosis is described as a single and separate idea, and better responses attempt to explain **how** the subprocesses of meiosis result in production of 4 n gametes from one parental 2n cell. Some responses use stages to describe activities, and some use more detailed phases. However, descriptions of process do not explain how genetic variation is attained nor why genomic integrity is maintained, that is, do not describe the crucial role of separation and/or crossing over of homologous pairs (though may mention these terms).
9 10 11	D	These responses start from an integrated understanding of the elements of meiosis that explain coherently how the products of meiosis are formed. The significant aspect of these responses is that they incorporate into the explanation the role of homologous pairs in the process. Better responses explain (by contrast to merely mentioning) crossing over and independent assortment of homologues. These more abstract elements explain **why** (in a non-teleological sense) meiosis maintains genomic integrity while halving chromosome number, and leads to genetic diversity in haploid cells.

In summary, this subsection has identified a hierarchy of 11 increasingly sophisticated categories of written response to meiosis questions, which students produced as part of the authentic assessment of the study context. These categories were grouped into the three broad groupings shown in Table 5.1, focusing on increasingly complex aspects of meiosis.

2a.ii: Fit of response categories to the 2-learning-cycle SOLO model

As outlined in Chapter 2, the two-learning-cycle per mode version of SOLO involves a hierarchy of five modes, which reflects the degree of abstraction of response. Within each mode are nested at least two cycles of levels, reflecting different structural complexity of responses. The relationship between the categories of response previously outlined and the SOLO model is assessed in this subsection, first at the broader scale of modes, and then at the finer scale of levels within each mode.

Relationship between categories and SOLO modes

The two modes particularly relevant to tertiary–level study are the concrete–symbolic and formal modes. The concrete–symbolic mode is characterised by declarative knowledge, using symbol systems to describe concrete referents, and the formal mode encompasses more abstract theoretical knowledge of constructs that do not necessarily have any direct empirical referent.

The broad groupings in Table 5.1 do appear to span the two relevant modes. Groups B and C contain responses which deal with concrete physical entities such as cells, chromosomes, chromatids, cells and haploid gametes, together with processes such as replication and splitting of these entities. They are therefore consistent with the concrete–symbolic mode.

Responses in Group B comprise statements focused on **what** meiosis is – a combination of stages/phases that results in a number of different cells from a single 2n nucleus. Most of the responses in Group C describe the detailed mechanics of **how** a 2n nucleus divides into four n gametes. Group B and C responses do not go beyond this, and do not integrate into their explanation some crucial aspects of meiosis such as the role of homologues in the maintenance of genomic integrity and enhanced genetic diversity. These issues, which reflect a higher–order level of abstraction, are addressed in responses in Group D. The categories of responses, therefore, are consistent with the modes of SOLO, with B and C representing the concrete–symbolic mode, and D representing the formal mode.

The difference in the level of abstraction of Group D responses, compared with Groups B and C, is based on the conceptual differences between chromosomes and homologous chromosome pairs. Different chromosomes are essentially different lengths of DNA coding for different genetic information and are represented by the concrete referents of different length lines in textbooks and lectures. This is consistent with the declarative knowledge typical of the concrete–symbolic mode.

Homologous chromosomes (homologues), however, are one step more abstract. They are pairs of chromosomes which have different parental origins and although coding for equivalent genetic information have different alleles. Homologous chromosome pairs are routinely represented (e.g., Knox, Ladiges, & Evans, 1994, p. 150) by two lines of the same length, (to indicate equivalent but not equal genetic information) but different colours (to represent the different parental origins). A full understanding of meiosis requires the student to understand the nature and role of homologues, which requires the student to be able to "look back" to the origin of the maternal and paternally derived chromosomes in fertilization. In the terms of Biggs and Collis (1991, p. 59) this is looking beyond the knowledge in the given system (meiosis), and therefore consistent with responses in the formal mode.

The groups of categories of response to the meiosis question, then, are consistent with the notion of modes as articulated by the SOLO model. The following subsection describes the extent to which the categories within each group fit with the structural complexity criterion used to delineate different levels within each mode.

Relationship between categories and SOLO levels

As described in Chapter 2, the two-learning-cycle per mode version of SOLO postulates at least two cycles of levels within each mode, that is, two rounds of unistructural, multistructural and relational responses, representing increasing levels of sophistication of response. Determining the level of response within any given mode involves identifying the structural elements of the responses, and how these are presented. In this subsection, the elements which are characteristic of each group of responses (mode) are described. The categories of responses within each broad group are then analysed in terms of the different elements they contain, and how these are integrated, following the theoretical framework of SOLO levels.

Group A

No elements were contained in this group of non-responses.

Group B (Concrete–symbolic mode, categories 2-4)

Responses in this group of categories focused on one or more of the following four central elements:

- Entities (e.g., cells, organisms, plants, chromosomes)
- Processes (e.g., splitting, "changing to form", reproduction)
- Sequence (e.g., Meiosis I & II, phase names)
- Products (e.g., sex cells, gametes, n)

The very few responses in category 2 focused on only one element; for example, the sample response in this category mentioned only the Sequence element. This mention of a single element is consistent with the *unistructural* SOLO level and responses were coded accordingly. In category 3, responses incorporated two or more of the elements mentioned above, but in an internally inconsistent or incomplete form which also often conflated meiosis with other concepts. These were coded as *multistructural.* Responses in category 4 integrated all the elements into a coherent and internally consistent description of what meiosis is, and were therefore coded as *relational*, but often also included other irrelevant information indicating that meiosis was not separated from other related concepts. The responses in these categories then were consistent with one cycle of levels in the concrete–symbolic mode, coded according to convention (e.g., Pegg, 2003) as U_1, M_1, R_1.

Group C (Concrete–symbolic mode, categories 5-8)

In this group of four categories the elements from Group B were present, usually with additional elements that focused on **how** the process of meiosis works. Better responses described, at least to some extent, the movement of chromosomes in an explanatory way. In this group of categories there were several additional elements all related to explanation of the intricate subprocesses of meiosis. The most important of these elements are:

- Chromosomes have been replicated (forming chromatid pairs, prior to MI)
- Chromosomes move/are pulled to opposite poles in MI/Anaphase I
- After MI there are two nuclei each with half the number of chromosomes
- Chromatids of each chromosome in the two nuclei separate and move/are pulled to opposite poles in MII/Anaphase II
- The result of meiosis is 4 nuclei, each with half the number of chromosomes as the parent cell.

This list is not exhaustive, but from the responses represents a minimum set of elements required to explain how meiosis works, at the concrete–symbolic mode.

Responses in category 5 expressed the Group B elements of meiosis into a coherent description, which was delineated from related concepts and represented the crystallisation of meiosis as a clear single idea. These were therefore an advance on the previous category and consistent with the description of a second more sophisticated *unistructural* level still within the same overall degree of abstraction, that is, within the same mode.

In category 6 the responses incorporated a number of the above Group C elements relating to how meiosis works, but in an incomplete or incoherent form, or as discrete, unrelated points. Diagrams commonly included standard textbook "summary" diagrams, as well as more explanatory custom diagrams depicting chromosomal movement over the different phases/stages of the process. Probably because of the sequential nature of the meiotic process, many responses provided a semi-sequential account of the process organised to some extent by phase or stage names, in a similar way to that used in standard textbook accounts. In this category, however, such responses were incomplete. For example, some elements were missing, or described out of order.

The responses in this category represented a gradation in quality of response, in terms of the number of different operations and entities they incorporated, and the completeness of the sequence described. This category contained the largest number and greatest diversity of responses, which is perhaps unsurprising given the number of elements that need to be brought together for a thorough description of the complex process of meiosis. Taken together this category spans a range of responses consistent with a *multistructural* level.

The relatively few responses in category 7 included those responses which incorporated all, or all but one of the Group C elements that need to be brought together for a full description of how a single diploid nucleus results in four haploid nuclei. They were, however, characterised by minor inconsistencies or inaccuracies which made them slightly less coherent than some of the better responses. They just about related all the elements into a coherent story that explained meiosis, but not quite. These responses were therefore somewhat transitional in nature, but were also coded as *multistructural.*

Responses in category 8 provided detailed descriptions of the processes of meiosis, integrating all the elements of this group of responses into internally consistent and coherent explanations that were therefore coded as *relational* responses. The relating, integrating feature was the sequence of physical movement of chromosomes relating the Group C elements listed above, which is necessary for the process to be expressed in a coherent explanatory form. The responses in this category alluded to chromosomes "moving", being "pulled", "aligning", "attaching to spindle fibres" and so forth.

Although the descriptions in category 8 were, as far as they went, an integrated explanation of how a diploid nucleus ends up as four nuclei with half the number of chromosomes as the parent, the responses went no further than that. These accounts, like those in the preceding categories, did not incorporate discussion of the crucial role played by the homologous chromosomes in the process. The responses in categories 5-8, therefore, represented a second cycle of unistructural, multistructural and relational responses in the concrete–symbolic mode, that is, U_2, M_2, R_2, with some transitional responses.

Group D (formal mode, categories 9-11)

A major disjunction within the overall qualitative variation of responses was apparent between responses in Group C and D. This reflects a move from the concrete–symbolic mode of Groups B and C to the formal mode of group D. Responses in Group D dealt coherently with the core unique feature of meiosis (as opposed to mitosis), which is the role of homologous pairs. Responses that made an incoherent reference to homologues (e.g., "chromosomes replicated to form homologues") were not included in this group of responses, but included in group C, as the abstract ideas relating to the nature of homologues and their role were not expressed.

- The elements of this group of responses included descriptions such as the following:
- Homologous pairs align and/or are separated in MI/metaphase-anaphase I.
- Portions of homologous chromosomes cross over in MI/metaphase I.
- Homologous chromosomes are independently assorted into daughter cells in MI/Anaphase I
- Elements 2 and 3 are responsible for genetic diversity and uniqueness of haploid meiotic products, and for the maintenance of the full genome in gametes.

In category 9 the responses coherently incorporated one of these more abstract referents into an explanation that was otherwise relational at the concrete–symbolic mode. These were coded as *unistructural* responses within the formal mode. Category 10 includes responses which incorporated elements 1 and 2 and were therefore consistent with a *multistructural* level. Finally, the highest quality responses were included in category 11, which integrated a discussion of homologues aligning, crossing over and randomly assorting as an explanation of meiosis. These were coded as *relational.* This group of categories then can also be viewed in terms of three levels: in this case U_{1F}, M_{1F}, R_{1F}.

In summary, the relationship between identified groups and SOLO levels outlined in the previous discussion is summarised in Table 5.2.

Table 5.2: Relationship between categories of written responses to meiosis questions and SOLO modes and levels

Group	Group description	SOLO mode	Cat #	SOLO level
A	Non-responses	prestructural	1	prestructural
B	Meiosis is not distinguished from other concepts.	Concrete–symbolic	2	U_1
			3	M_1
			4	R_1
C	Meiosis as a single and separate idea, and how it works explained.	Concrete–symbolic	5	U_2
			6	M_2
			7	M_2
			8	R_2
D	The role of homologous pairs in meiosis.	Formal	9	U_{1F}
			10	M_{1F}
			11	R_{1F}

Table 5.2 shows that the groups identified in the previous subsection are reconcilable with the two-learning-cycle per mode version of the SOLO model. Two cycles of levels in the concrete–symbolic mode are identifiable, as well as a single cycle in the formal mode.

2a.iii: Reliability and validity of SOLO categories

This subsection discusses the reliability and validity of the SOLO theoretical framework as a qualitative measure of written response. It outlines results of interjudge testing and correlations between SOLO categories and independently assigned marks for written responses.

The inter-judge test of the SOLO categories initially resulted in 18/20 (90%) agreement, and 19/20 (95%) after discussion. This indicates that responses to the specific question used in this study could be reliably assigned to SOLO categories. The criterion validity of the SOLO categories was tested by Spearman correlations between SOLO categories and independently assigned marks for the examination and practical test questions, which are shown in Table 5.3.

Table 5.3: Spearman rank order correlations between SOLO categories and independently assigned marks for meiosis questions in practical tests and examinations

	Year 1			Year 2		
	Prac test SOLO	Prac test mark	Exam SOLO	Prac test SOLO	Prac test mark	Exam SOLO
Prac test mark	**.77**			**.77**		
Exam SOLO	.58	.59		.54	.44	
Exam mark	.45	.54	**.73**	.42	.45	**.66**

Note: All correlations are significant beyond the .01 level

The bolded entries in Table 5.3 show strong positive correlations between SOLO categories and marks for written responses to meiosis questions in both practical tests and examinations. The non-bolded correlations show significant positive relationships between students' practical test and examination performance. The strong relationship between the two independent indicators of response quality in Table 5.3 suggests that the SOLO categories established in this study are as valid a measure of response quality as traditional marks.

In summary, the inter-judge test indicates that the SOLO categories are reliable measures of response quality. The correlations between SOLO categories and marks point strongly to the validity of the SOLO measures of learning quality. The SOLO categories established are thus used as indicators of the quality of learning outcome in following sections.

Summary 2a

Results presented in this section represent a hierarchy of 11 increasingly complex categories of written response to meiosis questions. These categories fit into three broad groups, which focused on increasingly complex aspects of meiosis. The first group represents the first cycle of the concrete–symbolic mode of SOLO, where meiosis is not distinguished from other concepts. In the second group of responses, which is consistent with the second cycle of the concrete–symbolic mode, meiosis is described as a single separate idea and how it works is explained. Finally the third group of responses represents the first cycle of the formal mode, and take into account the crucial and more abstract role of homologous pairs in meioisis. Within each of these modes, three categories of response could be identified as unistructural, multistructural and relational responses to the meiosis questions.

The results of the reliability and validity checks of the SOLO categories suggest that the model provides both reliable and valid measures of learning quality in the study context. The SOLO categories established are thus used as indicators of the quality of learning outcome in this study. The pattern of distribution of SOLO categories is described in the following section.

2b: Patterns of distribution of SOLO categories

This section describes the distribution of SOLO categories for written responses to the meiosis questions in the practical tests and examinations, across the sample of students. Three research questions are addressed in this line of inquiry:

2b.i: What is the pattern of distribution for the SOLO categories of responses?

2b.ii: Do internal and externally enrolled students studying in the same unit exhibit differences in learning outcomes?

2b.iii: Is there a relationship between learning outcomes, age and/or gender?

The first part of this section describes the distribution of SOLO categories for the different sub-samples (internal/external, Year 1 and 2), the results of tests assessing the homogeneity of the year 1 and 2 subsamples, and the frequency of the SOLO categories. The second part of this section compares the learning outcomes of internal and external students, in particular with respect to SOLO categories. Finally, the variables of age and gender are examined in relation to SOLO categories.

2b.i: Pattern of distribution for SOLO categories of responses

This subsection presents the frequencies of the different SOLO categories in the student sample. The data for each year of the study, and for each of the measures of learning outcome (practical test question and examination question) are shown in

Table 5.4. Data are presented as raw counts, and as percentages to aid comparison across different sized sub-samples.

Table 5.4: Frequency of SOLO levels in written responses to meiosis question in practical tests (internal students), and end of semester examination (both internally and externally enrolled students)

SOLO category	Year 1						Year 2					
	Practical test		Examination				Practical test		Examination			
	internal		internal		external		internal		internal		external	
		%		%		%		%		%		%
P	5	4.4	3	2.5	3	5.2	10	7.8	5	3.8	0	0
U_1	0	0	0	0	0	0	2	1.6	2	1.5	0	0
M_1	6	5.3	5	4.2	1	1.7	13	10.2	11	8.3	1	3.8
R_1	6	5.3	3	2.5	1	1.7	6	4.7	2	1.5	0	0
Total 1st cycle C/S mode	**12**	**10.6**	**8**	**6.7**	**2**	**3.4**	**21**	**16.4**	**15**	**11.3**	**1**	**3.8**
U_2	17	15	9	7.6	11	19	12	9.4	10	7.6	3	11.5
M_2	50	**44.2**	56	**47.5**	21	**36.2**	50	**39.1**	61	**46.2**	10	**38.5**
R_2	11	9.7	12	10.2	3	5.2	16	12.5	15	11.4	2	7.7
Total 2nd cycle C/S mode	**78**	**69.0**	**77**	**65.3**	**35**	**60.3**	**78**	**60.9**	**86**	**65.2**	**15**	**57.7**
U_{1F}	11	9.7	16	13.6	7	12.1	13	10.2	17	12.9	3	11.5
M_{1F}	4	3.5	11	9.3	9	15.5	5	3.9	9	6.8	5	19.2
R_{1F}	3	2.7	3	2.5	2	3.4	1	0.8	0	0	2	7.7
Total 1st cycle formal mode	**18**	**15.9**	**30**	**25.4**	**18**	**31.0**	**19**	**14.8**	**26**	**19.7**	**10**	**38.4**
Total responses	**113**	**100**	**118**	**100**	**58**	**100**	**128**	**100**	**132**	**100**	**26**	**100**

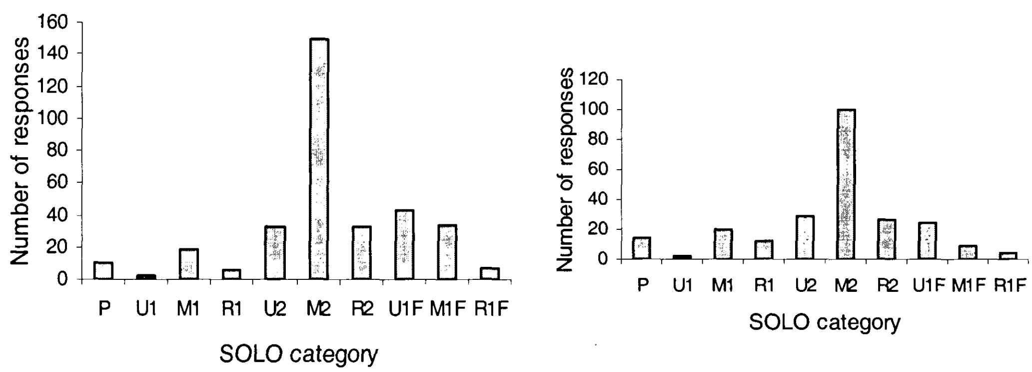
Note: Data are presented by raw count with percentages indicated in italics.

Of note in Table 5.4 is the consistently highest proportion of responses in M_2 in particular, and the 2nd cycle concrete–symbolic mode in general, for both the examination and practical test questions. The formal mode is the next most frequently represented, with fewest responses categorised in the 1st cycle concrete–symbolic mode.

The frequency of responses in each mode was compared to test the homogeneity of the students in the two years of the study, with respect to learning outcomes. No statistically significant difference was found between the distribution of SOLO modes for the examination question in year 1 and 2 of the study [$\chi^2(3, n = 336) = 3.333, p = .343$]. Similarly, the distribution of SOLO modes across the two years of the study for the internal practical test question is not significantly different [χ^2 (3, n

= 242) = 3.593, p = .309]. The students in each year show very similar patterns of learning outcomes, therefore the data were pooled across years to clarify the overall frequency distribution.

The pooled data for SOLO categories across both years are shown in Figure 5.1. Figure 5.1a summarises results for the examination question responses of all the students, while Figure 5.1b summarises responses of the internal students to the practical test question.



a: Examination question outcomes: all students

b: Practical test question outcomes: internal students

Figure 5.1: Distribution of SOLO categories for responses to the meiosis question in examinations (all students) and practical tests (internal students)

In Figure 5.1the high frequency of responses at M_2 and the 2nd cycle concrete–symbolic mode is again evident, for both practical test and examination questions. A comparison of response frequencies across the coarser scale of SOLO modes resulted in a significant difference for both the practical test question [χ^2 (2, n= 227) = 127.9, p < .001] and the examination question [χ^2 (2, n= 325) = 169.6, p < .001]. At the finer scale of SOLO categories there were also significant differences in response frequencies for both the practical test question [χ^2 (9, n= 242) = 295.8, p < .001] and the examination question [χ^2 (9, n= 336) = 494.1, p < .001]. These results, in combination with the frequency data in Figure 5.1, suggest that the frequency of responses at M_2 is significantly higher than in other categories.

In summary, this subsection has presented the details of the distribution of students written responses to the meiosis questions, across the different SOLO modes and levels. Student responses in each year of the study show similar distribution patterns. The results from the χ^2 tests in conjunction with the data in Figure 5.1 suggest that the SOLO category of M_2, and the 2nd cycle concrete–symbolic mode are significantly the most frequently represented in both the examination and practical test questions. The comparison of internal and external students is presented in the following subsection.

2b.ii: Comparison of internal and externally enrolled students

The issue of potential differences in SOLO categories for internal and external students is described in this subsection. The only measure of learning outcome applying to both internal and external students was the examination question, and Figure 5.2 shows the frequency distribution of SOLO categories for the separate internal and external student examination responses.

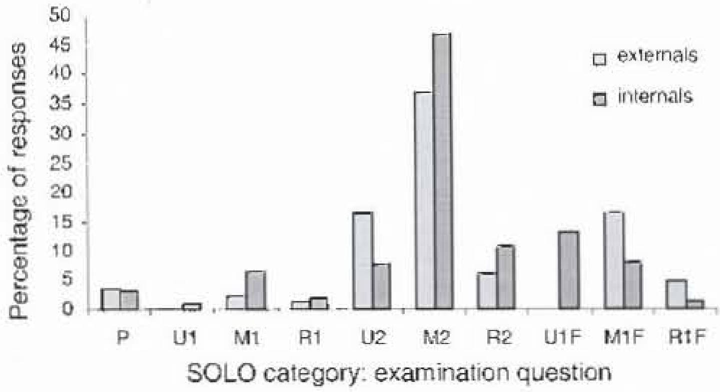


Figure 5.2: Percentage of internal and external student responses in different SOLO categories for examination question

As well as highlighting the significantly high proportion of M_2 responses overall, Figure 5.2 indicates a strong similarity in the patterns of learning outcomes of internal and external students in their response to the examination meiosis question. No statistically significant difference was found between the distribution of SOLO modes for internal versus external students' examination question responses [χ^2 (3, n = 334) = 5.891, p = .117]. This finding is corroborated by the lack of a significant difference in the mean mark attained in the exam question for internal (M = 2.72, SD = 1.16) and external students (M = 2.89, SD = 1.17); t(341)= -1.18, p = .24).

In a further comparison of the relative performance of internal and external students in the examination question, the SOLO levels outlined in Figure 5.2 were pooled into Low ($\leq M_2$) and High ($\geq R_2$) SOLO groups. The results for this comparison are presented in Figure 5.3.

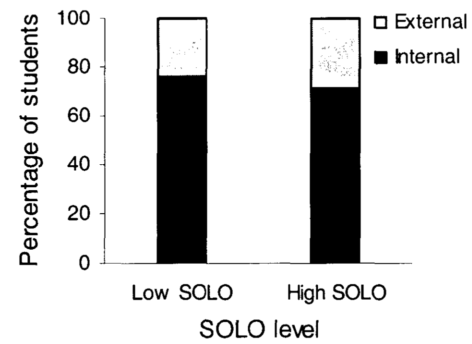


Figure 5.3: Proportion of internal and external students in Low (≤ M_2) and High (≥ R_2) SOLO categories

The data in Figure 5.3 show very similar proportion of Low and High SOLO responses in the internal and external groups. The ratio of Low:High responses for external students was 1.5:1, while it was 2:1 for internal students. There was no significant difference between the internal and external groups [χ^2 (1) = .74, p = .39].

In summary, the learning outcomes for the internal and external groups are very similar in the specific learning context at the focus of this study, with no significant differences detected between the Low (≤ M_2) and High (≥ R_2) SOLO groups.

2b.iii: Relationship between learning outcomes, age and gender

This subsection outlines results from an exploration of potential relationships between learning outcomes, age and gender. It shows the frequencies of High and Low SOLO responses that were tested for age and gender groups, and the results of cross-tabulating three SOLO modes with age and gender.

The frequency of Low (≤ M_2) and High (≥ R_2) SOLO responses to the examination question for three age groups is shown in Figure 5.4.

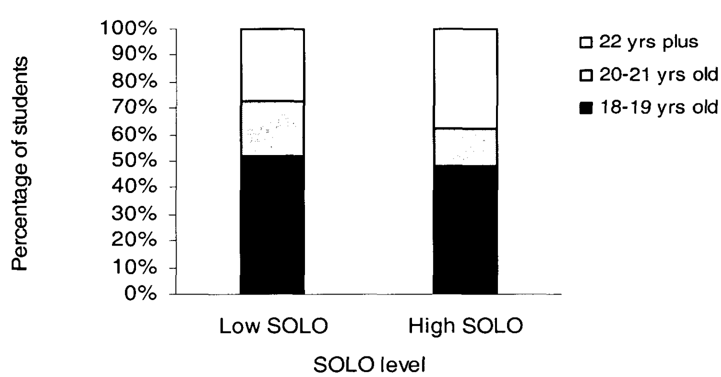


Figure 5.4: Proportion of students from three age groups for Low (≤ M_2) and High (≥ R_2) SOLO categories

Although Figure 5.4 shows a trend towards relatively more frequent High SOLO responses in the 22 years plus age group, there are no significant differences in frequency of Low and High SOLO levels across the age groups [χ^2 (2) = 4.43, p = .11]. When gender was included as a layer, no significant gender differences were evident (females [χ^2 (2) = 2.0, p = 0.36]; males [χ^2 (2) = 2.7, p = .26)]).

Cross-tabulations of the three SOLO modes with age groups also detected no significant difference between the frequencies of SOLO modes across the age groups [χ^2 (4) = 9.06, p = .06)]. Adding a gender layer to the cross-tabulation of modes resulted in too many cells with an expected outcome of less than five, so was inconclusive.

In summary, the results in this subsection indicate no relationship between the level of SOLO response to the examination question and the age or gender of the students.

Summary 2b

The results in this section show no significant differences between students' learning outcomes in each year of the study. The SOLO category of M_2, and the 2nd cycle concrete–symbolic mode are significantly the most frequently represented in both the examination and practical test questions, for all students. There is no detectable difference between the learning outcomes of internal or external students, based on comparisons of SOLO category frequencies and comparison of mean marks. There is also no significant relationship between the level of SOLO response to the examination question, and the age or gender of the students.

2c: Students' explanations of meiosis during interviews

This section describes the results from the analysis of the students' explanations of meiosis during one-to-one in depth interviews. The interviews of 16 students (11 internal and five external students) provided an opportunity to explore students' understanding of meiosis in depth, and to examine some of the areas of confusion apparent in written responses. This line of inquiry followed two research questions:

2c.i: What are the SOLO categories of students' verbal explanations of meiosis?

2c.ii: What are the common areas of confusion in students' understandings of meiosis?

The results below are organised in terms of these two questions.

2c.i: SOLO categories of students' verbal explanations of meiosis

The analysis of students' explanations of meiosis during interviews resulted in each student's response being categorised, according to the SOLO scheme that had been obtained from analysis of written responses. The SOLO category obtained by each interview participant is shown in Table 5.5, together with summary comments about the students' understanding of meiosis expressed during the interviews.

Table 5.5: Description of SOLO categorisation of students' understanding of meiosis as expressed at interview

Student, I/E & age	SOLO category	Researcher comments
Alex I, 19	M_1	Practical test response was that meiosis is the division of one diploid to 4 haploid cells. At interview Alex could not define or explain the nature of haploid or diploid, chromosomes, chromatids, homologues, replication & separation. The hierarchy of structures was confused. Exam answer incorporated more detailed reference to phases than prac test, but confused, incomplete and did not differentiate meiosis from mitosis.
Tina I, 18	M_2	Prac test response mentioned separation of homologues, and mentioned but did not integrate/relate some elements of 2nd cycle, C/S mode. Phases listed but not described. Interview highlighted confusion about the nature of homologues, chromosomes, chromatids, replication & separation events.
Adam E, 35	M_2?	Interview demonstrated confusion about the relationship between chromosome & chromatid, did explain nature of homologues. Not clear from interview whether Adam could relate the elements of the 2nd cycle, C/S mode.
Amanda E, 21	M_2	At interview could not explain origin & nature of homologues & said that daughter cells were identical.
Tom I, 19	M_2	Prac test response very brief, conflated meiosis with fertilisation, said that cells divided into chromatids. At interview showed confusion about chromatids, chromosomes, homologues, replication & separation. Unaware of the behaviour and significance of homologues. Said that "went blank" in the prac test, left that question till last.
Liam I, 18	M_2 (- R_2)	In his prac test response Liam incorporated all the elements of an R_2 response, in addition to a reference to homologues separating which lead to the U_{1F} code. At interview, however, he showed confusion about the nature of homologues, chromosomes & chromatids. Homologues said to form from replication of single chromosome. After slight prompting and explanation of homologues Liam recreated an R_2 response.
Kim I, 18	M_2 (- R_2)	In the prac test Kim included two of the elements of responses in the 2nd cycle, C/S mode. No attempt was made to relate these elements. At interview Kim demonstrated that she knew more than she put down in PT answer, including activities of various phases. Not clear about exact relationship between chromosomes & DNA, could not explain nature of homologues.

Table 5.5 (cont.)

Jenni I, 18	M_2 (- R_2)	Prac test response referred to homologues & their separation in MI, as well as integration of all elements of 2nd cycle, C/S mode which lead to the U_{IF} code. At interview confused about hierarchy of genes, DNA and chromosomes, unsure about the nature of homologues.
Charlie I, 21	R_2	Prac test response referred to homologues & their separation & crossing over in MI , as well as integration of all elements of 2nd cycle, C/S mode which lead to the M_{IF} code. At interview Charlie was slightly confused about the nature of homologues & their difference from replicated chromosomes.
Ryan I, 20	R_2	At interview integrated elements of elements of 2nd cycle, C/S mode. Some confusion about nature of homologues & elements of formal mode
Laura I, 19	M_{IF}	At interview described elements of formal mode in particular role of homologues as well as integrating elements of elements of 2nd cycle, C/S mode. Although could describe homologous pairs seemed slightly confused about their different parental origins.
Ruth I, 18	M_{IF}	At interview initial confusion between terms homologues & chromatids was resolved after probe, as was separation of homologues in MI. Said that she thought the prac test question implied a broad definition of meiosis rather than step by step description.
Paul E, 44	M_{IF}/R_{IF}	At interview Paul stated that homologues formed by replication, resolved this himself after probe. Otherwise could relate elements of formal mode but extent of integration not clear from interview.
Kirsty I, 19	R_2 (-R_{IF})	At interview, initial confusion that homologues formed by replication resolved after probing. Could describe crossing over after prompting. Responses very tentative.
Rob E, 33	R_{IF}	At interview integrated elements of 1st cycle, formal mode and clearly articulated origins and nature of homologous pairs.
Jacinta E, 58	R_{IF}	At interview showed extremely thorough understanding of all elements of meiosis. Went beyond all other respondents in contrasting independent assortment (element of the 1st cycle, formal mode) with sex–linked genes.

Notes:
Interview data not available for two students: one interview ceased after 5 minutes as student was feeling stressed, one malfunction of tape.
E = Externally enrolled; I = internally enrolled;
SOLO categories in parentheses indicate level achieved after prompting

As shown in Table 5.5, most students responded at the 2nd cycle, concrete–symbolic mode. No student interviews were coded as unistructural. Of the five external students, three responded in the formal mode and these were among the four oldest students interviewed. Of the 11 internal students, six responded in the Low SOLO group ($\leq M_2$) and five in the High SOLO group ($\geq R_2$). In terms of SOLO modes, nine of the 11 internal students responded at the concrete–symbolic mode while only two responded in the formal mode. These results are indicative of some age and/or enrolment differences between concrete–symbolic and formal modes.

Also evident from the interviews was the very tentative nature of several students' understandings. The coding for several students in Table 5.5 reflects this, with students responding at higher SOLO levels than their initial attempts after some prompting. For example, Kirsty initially responded at least at R_2, but demonstrated some confusion about how homologous pairs are formed. She resolved this herself after a few probing questions, and after some limited prompting described all the elements of meiosis at the formal mode, in a relational manner; that is, at the R_{1F} level.

In summary, students' verbal explanations of meiosis were most frequently at the 2^{nd} cycle in the concrete–symbolic mode, with some evidence of older/external students tending to respond in the formal mode. Many students' explanations were tentative, and several were extended and improved after probing or prompting questions were asked. The students in general also evidenced an array of misconceptions and areas of confusion which are outlined in the following subsection.

2c.ii: Students' understandings of meiosis

The interviews also highlighted some of the areas of confusion and alternative conceptions about meiosis. These are summarised below, with some indicative quotations from the interview transcripts.

One commonly expressed area of difficulty was the nature of homologous pairs. Several students showed misconceptions about how homologues are formed, how they differ from replicated chromosomes, and therefore how their separation maintains the full genome in meiosis.

> I: So what's that now?
> S: Two chromatids joined with something marked on them.
> I: OK, so that means they're…
> S: The same.
> I: Exactly the same?
> S: Mm.
> I: So what did you say that was?
> S: Two chromatids.
> I: Two chromatids. And what's the whole structure called?
> S Homologous chromosome.
> I: The whole one?
> S: I don't know.
>
> (Laura)

I: When you say: "join with homologous pairs in prophase", what do you mean by that?
S: Homologous pairs? They're the same, aren't they?
I: The same?
S: Yeah like ident...ohh homologous, yeah, ohh. No, no sister chromatids are the same aren't they and homologous pairs are — I don't know. I think I just added a few terms...
I: [...] You said: "crossing over". Do you know what crossing over happens to? Any chromosomes, or...?
S: Sister — oh no, homologous chromosomes.
I: Homologous chromosomes. And which are the homologous ones here?
S: Like that was just something that I, they must have said, you know — sister chromatids join...I mean not sister chromatids — could be sister chromatids?

(Jenni)

I: Yeah. So if you had to define homologous chromosomes, what are they?
S: They are two sister chromatids that are the same? Replicated sister chromatids? I dunno.
I: Do the chromosomes that originally came from the mother all go to one end and the ones that originally came from the father, do they all go to the other end?
S: Um, once they've shared DNA material yeah I suppose so because they're lined up to go on each other's — to — along the plate so I suppose they have to.

(Charlie)

Many students also expressed confusion about terminology, especially the difference between chromosomes and chromatids (and sometimes centromeres).

I: What do you call this? What's that unit there?
S: I've never known the difference between one of them and one of them because my teachers used to call them chromosomes, and then say that chromosomes replicate and then they're a chromosome, but these are chromatids! So I'm thinking...what's the difference, and why are they called the same?

(Ruth)

I: So what did you just do there?
S: DNA replication.
I: So what does that create?
S: [pause] Sister chromatids which are — .
I: Which are the sister chromatids?
S: [long pause] I always get confused.
I: Now what's the confusing bit?
S: Well, one of the main things I find hard is, is that a chromosome there? A single one?
I: Yes it is.
S: So, that there is also a chromosome. That is where the confusion starts.

(Liam)

For some students there were apparent misconceptions about the hierarchy of structures involved in meiosis (DNA, genes, chromosomes and cells):

> I: Where would you find a chromosome?...where physically?
> S: DNA.
> I: Are they in the DNA?
> S: No, I think chromosomes are...they're in the genes — chromosomes.
> I: OK, so are they sort of, smaller than genes?
> S: Oh, I always get confused with this one. I always get — like, there's the whole hierarchy of chromosomes, genes, DNA so they always get confused. Like I usually, before I go into a test I make sure I can make up all these limericks in my head so I can say that goes first, and that goes there, and...
> I: Yeah, OK, um, so what's it made of? What's a chromosome made of?
> S: Is it made of DNA?
> I: Yes.
> S: So it goes: genes, chromosomes, DNA, does it?
>
> (Jenni)

> S: The chromatids are in a double helix then they wind up completely like twice to make the chromosome.
> I: So how many strands of DNA in total are in one chromosome? [picture of unreplicated chromosome]
> S: Two.
> I: And how many chromatids?
> S: Two
> I: So there's two chromatids in there?
> S: Yeah. In one there should be two chromatids because a chromatid is a strand of DNA...Chromatid is a half. Chromosome is a full, so that's just one chromosome, two chromatids...but they're the same.
> I: If there were already two chromatids in this chromosome, how many chromatids in total in this chromosome? [picture of replicated chromosome]
> S: There would be four.
> I: Four chromatids.
> S: Yeah, they're two there...I'm thinking that's only two? Oh no they're two — they're joined together.
> I: What joins together?
> S: Oh No they don't. I'm thinking of an entirely different phase. That's only two.
> I: So how does a chromatid relate to DNA?
> S: A chromatid is 1 strand of DNA.
> I: One unzipped strand or zipped?
> S: Zipped up I think
>
> (Tina)

In summary, many of the subordinate concepts of meiosis, and the relations between them, caused great difficulty for several students during the interviews. Only two students interviewed, Rob and Jacinta, articulated a thorough understanding of meiosis at the level explained in the first–year biology textbook.

Summary 2c

This section has described the findings from the interviews, where students were asked to explain verbally the process of meiosis. Most students responded at the 2nd cycle, concrete–symbolic mode. Some differences between internal and external students and/or younger and older students were suggested by the interview data. Three of the five external students responded in the formal mode and these were also considerably older than all but one of the other students interviewed. Although the responses of the 11 internal students were evenly distributed between the Low and High SOLO groups, only two responded in the formal mode.

The interviews also illustrated some misconceptions and areas of confusion about meiosis, specifically relating to homologues, terminology and the hierarchy of biological structures involved in meiosis. Only two students could explain meiosis at a level comparable to the first–year textbook, albeit with much less detail. The relationship between the interview responses and these students' written responses to meiosis questions is outlined in the following section.

2d: Relationship between written and interview explanations of meiosis

Analysis of interview transcripts of the sixteen individual interview participants generated a SOLO code for each student's explanation of meiosis. This was in addition to the codes assigned from the analysis of their written responses to meiosis questions in the practical test and/or examination. This section outlines the relationship between SOLO categories of students' written responses to meiosis questions and their explanations of meiosis during interview. This line of inquiry was directed by the following research question:

> 2d.i: How does SOLO categorisation of students' written responses to meiosis questions in the practical test and examination question accord with their verbal explanations at interview?

The SOLO categories of students' interview responses together with codes for relevant practical test and examination questions are shown in Table 5.6.

Table 5.6: SOLO categories of students' understanding of meiosis as expressed at interview, with associated practical test and examination question responses

Student	Enrolment	SOLO category: Interview	SOLO category: Prac test	SOLO category: Exam
Alex	I	M_1	U_2	M_1
Tina	I	M_2	M_2	No response
Adam	E	M_2?	N/A	U_{1F}
Amanda	E	M_2	N/A	M_{1F}
Tom	I	M_2	R_1	R_1
Liam	I	M_2 (- R_2)	U_{1F}	M_{1F}
Kim	I	M_2 (- R_2)	M_2	U_{1F}
Jenni	I	M_2 (- R_2)	U_{1F}	M_2
Charlie	I	R_2	M_{1F}	M_{1F}
Ryan	I	R_2	R_2	M_2
Laura	I	M_{1F}	M_{1F}	R_2
Ruth	I	M_{1F}	M_2	M_{1F}
Paul	E	M_{1F}/R_{1F}	N/A	R_{1F}
Kirsty	I	R_2 (-R_{1F})	R_2	M_2
Rob	E	R_{1F}	N/A	M_2
Jacinta	E	R_{1F}	N/A	M_{1F}

As shown in Table 5.6, there is considerable variability between SOLO codes across the three measures of learning outcome. These are discussed in terms of practical test and examination responses.

Relationship between interviews and practical test questions

A comparison of SOLO categories across practical test responses and the interviews that took place 9 – 12 days later indicates considerable variability. Of the internal students, five (Kim, Tina, Ryan, Laura and Kirsty) received the same coding for their interview and the practical test. This suggests a degree of stability in their understanding of meiosis. Two students (Tom and Ruth) demonstrated greater understanding of meiosis in interview than they had in their practical test.

Aspects of the interviews for both of these students suggested possible explanations for this. Tom had gone blank and left the question till last in the practical test:

I: You obviously did pretty well in the rest of the test to get 20 out of 30 and get 0 for that one. That's going pretty well for the rest of the test.
S: I dunno, I just went blank in that question. Like it's always happening — sometimes you go blank in one question and leave it until you come back and do it later.
I: Did you do that one at the end? Was it a last minute...?
S: That was the last thing before I did leave.

(Tom)

Ruth had interpreted the question in a particular way:

I: So, with this prac test...if you had that again would you change anything?
S: I'd change the question.
I: What would you say?
S: Well, the way they've said it it doesn't state that you have to say anaphase — 'cause I looked at the answers that they've got out there. And they've basically just done each step. What it is, what happens and like that. Whereas that [the question] implies a more broader — for me anyway — a more broader definition of meiosis.
I: if this answer to this question now that you think, how fully did you answer the question that was given, and would you change anything? Could you add to it, extend it?
S: Yeah, I'm sure I could.
I: And how? What would you add?
S: [rereads answer] I'd probably say what the process is more. Like when I say the daughter cell then divides again, I'd say the homologous chromosomes separate and there's crossing over and stuff like that and then they divide yet again to form 4 cells and there could differences...just between each genetic makeup of the cells and stuff like that.
I: So you knew that, you just didn't put it because you didn't think it was asked for?
S: Yeah.

(Ruth)

These excerpts from the transcripts highlight two of many possible factors that influence students' responses to test and examination questions other than their understanding of the content. For Tom and Ruth, it seems likely that their practical test responses may have underrepresented the extent of their understanding of meiosis.

Four students (Alex, Liam, Jenni and Charlie) had a lower SOLO rating from interview responses than the preceding practical test, and the responses of three of these students (all but Alex) went from the formal mode in the practical test to the concrete–symbolic mode at interview. This may suggest that their understanding of meiosis was somewhat superficial, and that their responses in the practical test may have overrepresented the extent of their understanding of the content. The students may also have been less motivated to perform well in the non-assessment context of the interview, although they appeared to be genuinely trying hard to answer the interview questions.

Relationship between interviews and examination questions

Comparing students' interview and examination responses demonstrates, again, considerable variation in response quality across the different contexts. One student (Tina) left the examination question blank so no comparison with interview data was possible. Only three students (Alex, Jenni and Ruth) responded at the same level in the examination question and the interview. Six students (Tom, Ryan, Laura, Kirsty, Rob and Jacinta) demonstrated greater understanding of meiosis in interview than they did in the later examination question. This implies either that their understanding had deteriorated in the intervening weeks, or that their responses in the examination question underrepresented their understanding for some reason. A further six students (Adam, Amanda, Liam, Kim, Charlie and Paul) performed better in the examination than during the interviews. This may suggest either that their understanding had improved during the intervening weeks (possibly on account of studying for the examination), or that their responses in the examination may have overrepresented the extent of their understanding of the content.

Summary 2d

This section has focused on the relationships between the verbal and written explanations of meiosis by the interviewed students. In both interview and written responses, most students were categorised in the 2nd cycle, concrete–symbolic mode. Only a small minority of students responded at the same SOLO level across interviews and written responses.

Overview

This chapter has outlined the results pertaining to theme 2 of this study, which relates to students' learning outcomes in relation to the study context. The measures of outcome used were students' written and verbal responses to questions about their understanding of meiosis, a central and core aspect of the study topic.

The first line of inquiry in this chapter (2a) focused on students' written responses to meiosis questions in practical tests and examinations. The qualitative variation in responses could be described in a hierarchy of 11 categories, which were consistent with the two-learning-cycle version of the SOLO model. One group of categories which focused on what meiosis is, reflected the first cycle in the concrete–symbolic mode. The next group of qualitatively better responses described how meiosis worked, and represented the second cycle in the concrete–symbolic mode. The final group of categories which described the more abstract role of homologues in meiosis were consistent with the first cycle in the formal mode. Within each of these modes, three categories represented increasing structural complexity of response, ranging from unistructural, through to multistructural and relational responses.

The second line of inquiry in this chapter (2b) was the pattern of distribution of SOLO categories across the study sample. The major finding was that the vast majority of responses were in the M_2 category. Hence, most responses described a number of the elements of how meiosis works, but were not coherently integrated, and did not take into account the role of homologues. No differences between internal or external students were apparent.

The third line of inquiry in this chapter (2c) related to students' verbal explanations of meiosis during an interview. Most students described meiosis is a way consistent with the M_2 category, with some evidence of older, external students responding more in the formal mode. From the interviews, many areas of confusion in students' understandings of meiosis were evident.

The final line of inquiry in this chapter (2d) was to investigate the relationship between qualitative and quantitative data, for those students interviewed about their understanding of meiosis. There was little consistency between individual students' written and verbal explanations of meiosis. The same general trends, however, were apparent in both qualitative and quantitative data, with most students' responses categorised in the 2^{nd} cycle of the concrete–symbolic mode.

In general, the results presented in this chapter provide a theoretically grounded description of a hierarchy of levels of responses to meiosis questions, in response to theme 2 of the study. The results of the analyses of learning outcomes suggest that the bulk of students studying the topic had a partial understanding of meiosis and several areas of confusion about terminology and subordinate concepts. The relationship of these learning outcomes to the students' learning approaches previously described, is presented in the following chapter.