Chapter 8

Conclusions

Introduction

This chapter presents a discussion of the limitations, findings and significance of this study. It begins with an outline of possible limitations to the research, as a background for subsequent discussion and conclusions drawn. The aims of the study are then summarised in relation to the three study themes posed in Chapter 2. This is followed by a synthesis of the major findings, which have been outlined in Chapters 4, 5 and 6, and discussed in relation to the literature in Chapter 7. The chapter then considers the implications of the study for practice, for theory and for further research, and concludes with an overview of the research outcomes.

Study limitations

The limitations inherent in the design of this study, and in the qualitative and quantitative methods used, were discussed in Chapter 3. This section describes potential limitations and issues that arose during the course of the research. These issues include researcher influences following interviews, the amount of variance captured by factor analysis of the MSPQ, response sets, non-response bias and researcher bias in categorising students' written responses to meiosis questions.

One ethical and practical issue associated with this study is the effect of the research and the researcher on the learning of students. In particular, the research interviews may have influenced the later responses of the interviewed students to the meiosis question in the examination and, therefore, their marks. Students were asked in-depth probing and prompting questions during the interviews to gauge their understandings of meiosis, and the researcher later explained aspects of meiosis in the spirit of "fair return" for their participation. The explanations or even the interest and interaction of the researcher may have facilitated the learning of these students, which raises issues about equality of learning support and opportunity.

In practical terms, the different researcher explanations and interactions with interviewed students may have influenced later examination responses by those students. This may have affected the comparison of interview and examination responses; however, given the time between the interactions and the examination, this effect is likely to have been minimal. In addition, because the number of students interviewed was low relative to the total number of participants, the researcher effects are unlikely to have compromised the validity of the quantitative analyses.

Another possible limitation of the study, or at least an aspect that should be highlighted, is the relatively small amount of variance explained by the factor analysis of the MSPQ. Although the variance explained (33%) was comparable to that obtained in previous uses of the instrument (see Chapter 3), it was still considerably lower than the 50-60% usually obtained in factor analyses (Meyer & Shanahan, 2003, p. 9). The validity of the MSPQ, though, was also examined using the entirely different approach of Rasch rating scale analysis, which clearly indicated that the deep and surface scales had acceptable validity and reliability.

A further limitation of the quantitative data collected by responses to the MSPQ is the issue of response sets. It is possible that the number of responses indicating "mixed" approaches to learning may have been inflated by some students tending to either agree or disagree with all items. The interview data showed that response sets may have been an issue with some students, whose responses to the MSPQ suggested mixed approaches, but whose description of their learning activities at interview suggested one predominant approach to learning. Again, response sets are an issue in any questionnaire based study, and their effect in this case would have been to overestimate the incidence of mixed approaches, rather than skewing the results in the direction of either deep or surface approaches. The incidence of what has been called "mixed" approaches in this study, as in other data collection exercises of this type, should therefore be interpreted with caution and bearing in mind the possible influence of response sets.

The quantitative aspects of this study may have contained some bias caused by non-participation or non-response from subgroups of students. Particular examples include students who did not attend the relevant practical sessions, or those who were anxious about taking the time needed to respond to the questionnaire out of their practical session. In the reporting of this study, therefore, response rates have been disclosed and the samples for each year of the study described in detail to allow comparison with other studies.

A particular issue in this respect is the lower response rate for external students in the second year. Richardson (2000, p. 181) argued that comparisons across groups with different response rates are not valid, as respondents are likely to differ from non-respondents in many respects including learning approaches and outcomes. In the analysis of this study, the attributes of the sub-samples in year 1 and 2 of the study have been described and compared. There was no significant difference between the learning approaches or outcomes of the external cohort between year 1 and 2 of the study. This equivalence supports the validity of comparisons of learning approach for the pooled data, and that the study validity has not been seriously compromised by non-response of external students in the second year of the study.

Another issue potentially affecting the results of this study was that external students responded to the MSPQ while attending their residential school. Although instructed to respond in the context of their overall study of the topic, it is possible that they may have responded differently had they filled out the questionnaire at home, away from the intense study of the residential school. This possibility, though, was countered by the close accord between the findings from MSPQ responses and the interviews, which had been conducted with off–campus students when they were back at home. The agreement between interviews and MSPQ responses indicated that students' self-reports of their learning approaches did not differ markedly across home/university contexts.

The final issue discussed in this section relates to researcher bias in the categorisation of written responses to the meiosis question. This categorisation was undertaken in part to assess the validity of a recent version of the SOLO model, which in a sense had already been assumed in the development of the research questions. The analytical process described in Chapter 5 was that responses were grouped into categories of "like" responses, for later comparison with the hierarchy of categories within the SOLO theoretical framework.

During the initial categorisation, the researcher tried to suspend or "bracket" her pre-existing knowledge of the SOLO framework and bias towards it, but this was not fully possible. Interestingly, the more that bracketing was being implemented, the easier the categorisation process became. Nonetheless, the inclusion of different elements of meiosis remained as one of the decision criteria in the categorisation process. This bias is explicitly acknowledged here. Although different categorisations of responses were doubtless possible, and although the final categorisation was influenced by the perspective of the researcher, a coherent categorisation was established, and verified by two co-researchers. This categorisation was congruent with the theoretical framework of the SOLO model.

Synthesis of study

This research was driven by the three study themes outlined Chapter 2. These were:

1. What approaches to learning are adopted by students in a particular tertiary science context?
2. What is the variation in the quality of learning outcome from that particular context, as measured by the two-learning-cycle per mode version of the SOLO model?
3. What, if any, is the relationship between learning approach adopted and SOLO levels?

These three themes were explored in a research setting of a rural university, with students of diverse ages and educational backgrounds. Many of these students have a different cultural capital to students in larger metropolitan universities, in which most previous Australian research has been conducted. In addition, students were enrolled in either internal or external modes, while sitting the same examination and covering the same content.

The conceptual context for the exploration of learning outcomes was the concept of meiosis, which was a central aspect of the topic at the focus of this study. The teaching context was typical of traditional first–year introductory biology units, characterised by teacher–centred information transmission, heavy content, and at least half the assessment by examinations.

Against this background, first–year biology students responded to a topic–specific version of the MSPQ, in relation to their approach to studying the two–week topic of *Cellular and Organismal Reproduction*. The results supported the validity and reliability of this instrument in the study context, for both internally and externally enrolled students. Very few internal students showed strongly deep approaches. The majority adopted either a mix of deep and surface approaches, little use of either approach, or a predominantly surface approach. While nearly half of the external cohort also adopted a mix of both approaches according to the MSPQ, over a third reported a predominantly deep approach and very few reported a strongly surface approach to their learning. In short, the younger, internally enrolled cohort reported significantly greater use of surface approaches than the older, externally–enrolled cohort, and significantly less use of deeper approaches.

These results were broadly consistent with students' expressions of their approaches to learning at interview. Comparisons of individual students' interview and MSPQ responses, however, suggests that in some cases interviews were more powerful than the MSPQ at discriminating between learning approaches, and that the MSPQ may have inflated the proportion of "mixed" approaches to learning. This result is unsurprising, given the power of interviews in teasing out and exploring aspects of complex issues such as learning. Nonetheless, the MSPQ results did provide some general trends in learning approaches that were associated in a theoretically coherent way with other variables such as age. The combined use of both data sources maximised the advantages of using a quick, self-report instrument to access quantitative data, together with fewer, more time–consuming interviews providing richer qualitative data.

The paucity of deep approaches to learning in the internal cohort is of concern. It is theoretically interpretable by a combination of these students' younger ages, and the boredom and perceived irrelevance they experienced in their learning – a problem common in traditional introductory science units. This finding lends some support to questions about the relevance of learning approach theory to school leavers who may have different values to those espoused in the higher education agenda.

The fact that external students reported deeper approaches to learning, despite their relative isolation and lack of interaction with other students and staff, supports the distance education model used in the unit. The combination of the residential school and self–paced study of appropriate materials was effective in engaging many first–year off–campus students with their learning, relative to their on–campus counterparts. The issue still remains, though, that 20% of the external cohort and 10% of the internal students did not adopt any real approach to learning, and therefore were seemingly unengaged with the topic. These students in particular may have benefited from some more interactive aspects to their learning environment, to facilitate their engagement with the topic and social construction of knowledge.

The second theme of learning outcomes was investigated by analysing the students' written responses to questions about meiosis, from actual topic assessment tasks. The same students who had been interviewed about their learning approaches were also asked to explain the process of meiosis. The categorisation of qualitatively different written responses was reconcilable with the recent two-learning cycle version of SOLO. This supports the validity of the most recent SOLO model, which has not previously been tested in an assessment context in tertiary science. Further support for the criterion validity of the hierarchy of SOLO levels was their correlation with marks, which were an independent quantitative measure of students' responses.

The vast majority of responses fell within the multistructural category in the second cycle of the concrete–symbolic mode of SOLO (M_2). That is, they contained a number of elements relating to how meiosis works, but these elements were unintegrated and did not include more abstract aspects of meiosis relating to the role of homologues. No statistically significant differences could be detected between the learning outcomes of internal and external students, or between different age groups, which was in contrast with the learning approaches aspect of the study. Most students, therefore, did not attain the degree of abstract, theoretical knowledge that is the purported target of tertiary education.

The array of misconceptions and areas of confusion evident in many students' responses to questions about meiosis also suggested that the concept was not well understood. Student difficulties in understanding meiosis are also evident in a number of other studies. Some of this difficulty appears to be related to confusing terminology, and to insufficient explicit conceptual links between DNA synthesis and chromosome replication. Analysis of the most common Australian secondary science books provides support for this possibility.

The final study theme related to the theoretically predicted relationship between outcomes and approaches. In terms of the MSPQ responses, deep approaches were associated with better examination–question outcomes only for the older, external cohort, while surface approaches were associated with poorer examination–question outcomes only for the younger, internal cohort.

The absence of a relationship between deep approaches and better–quality outcomes for the internal cohort contrasts with much previous Australian research, mostly conducted at larger metropolitan universities. This result is perhaps explicable considering the paucity of predominantly deep approaches in the internal group. If so, this again highlights potential limitations of the applicability of the theoretical nexus between learning approaches and outcomes to the diverse group of young internal students in this study.

The association between surface approaches and poorer quality examination outcomes for the internal group, contrasted with the lack of such an association in the practical tests. Reproduction of superficially learned information appeared to be more achievable in the practical test situation. Repeated assessment of this type might therefore have the undesirable consequence of rewarding a surface approach, which may encourage students to persist with learning behaviours that may hinder longer term meaningful understanding.

Further findings from this theme related to students using mixed approaches to learning, or very little of either approach. In the case of the total cohort and the internal group, poorer outcomes were at least as frequent in groups of students with essentially mixed approaches, than in groups with strongly surface approaches. For the external cohort, it was students with essentially no approach to learning who had the poorest–quality outcomes. Both of these results accord with previous findings.

For those students who were interviewed, deep approaches were usually associated with explanations of meiosis at or above the relational level within the second cycle, concrete–symbolic mode (R_2). These explanations provided a coherent integrated explanation of how meiosis works, though not taking into consideration the more abstract issues of the role of homologues. By contrast, surface responses were mostly associated with explanations that were below the response level R_2, and did not provide a description of how the process of meiosis leads to its products. This result supports the relationship that had been predicted on the basis of previous research using earlier versions of the SOLO model.

Finally, this study found that as a group, the older, external enrolled cohort demonstrated equivalent outcomes to the younger internal cohort. This was despite their generally deeper learning approaches, and previous evidence suggesting that mature–aged students generally have better learning outcomes. Although possibly a statistical limitation of the bulk of responses at M_2, this result may reflect intrinsic problems with examination assessment, and external students knowing more than they expressed in examinations. This possibility is supported by the fact that students with deep approaches explained meiosis at interview better than their written examination responses. Better examination technique from recent school experiences, or better prior knowledge, may have contributed to the equivalent outcomes of the internal cohort, which were achieved despite their less desirable, more surface learning approaches.

Implications for practice

This section outlines the implications of the findings of this study for various aspects of teaching and learning practice. The first area discussed is assessment, particularly the utility of the SOLO model and the role of examinations. The implications of the study for teaching of meiosis in lectures and practical work are then outlined. Finally, issues related to the learning approaches fostered by the learning context are discussed.

In terms of assessment, the results of this study partially support the conclusion by Boulton-Lewis (1998a, p. 216) that SOLO has potential in teaching and assessment at the tertiary level. The SOLO assessment of learning outcomes did show a theoretically more coherent relationship with internal students' surface approaches than did standard assessment marks. It was also found that the new SOLO model, in practice, did reflect differences in response meaning, which is an advantage over previous versions. This closer connection with meaning, as was evident in the application of the new version of SOLO, has been argued to be a more valid indicator of learning outcomes (Trigwell & Prosser, 1991).

The process of categorising written responses and coding according to SOLO has implications for the role of the two-learning-cycle version of SOLO in grading of examination responses. Establishing the SOLO levels for meiosis was a complex and time–consuming task. Establishing categories of responses for every question would be impractical for routine grading of examinations covering the diversity and complexity of concepts in a first–year biology unit. Nonetheless, once categories are established, the SOLO model does provide a tool for quickly evaluating meaningful qualitative differences in response, which could be applied to different assessment tasks. In this context of tertiary level biology examinations, SOLO may also have practical value in helping to construct appropriate assessment questions that elicit relational responses.

The results of this study support the widespread criticisms that have been directed at examinations for rewarding surface learning approaches. This was apparent especially in the practical test for the internal group, where there was no negative correlation between surface approaches and outcomes. It is possible that alternative assessment of practical work may ameliorate this problem of rewarding surface approaches. Potential assessment alternatives could include group problem–based activities, self–paced mastery learning tasks, or a different style of questioning in practical tests.

The final implication of this study in relation to assessment is that the external, mature–aged students may be at a disadvantage in examinations. Their more desirable learning approaches did not result overall in better examination question outcomes. The relatively deep learning approaches and more complete understandings of some students (mostly in the older, external cohort) considered by their lecturer as "better at learning" might be better recognised and rewarded by a different assessment strategy. The problems of using formal examinations in assessment of mature aged students and some alternative approaches have been discussed by Sutherland (1998, p. 199).

As well as implications for assessment, this study has implications for the teaching of meiosis in both lectures and practical sessions. The finding that so many students in this study responded to the meiosis question at the concrete–symbolic mode, and demonstrated such confusion about the terminology, strongly support Kindfield's (1994) suggestion to use only the terms "replicated" and "unreplicated" chromosomes and to avoid using the term "chromatids" altogether. The problem with this, though, is that it would not conform to the current practice in tertiary biology texts. These findings also indicate that the mechanism of chromosome replication should be linked more explicitly and concretely to DNA synthesis and replication in secondary and tertiary teaching of cellular reproduction. If students understand the basic structure of the DNA double helix, demonstrating the simple mechanics of unzipping the helix and replication of each strand (to form a replicated chromosome) is relatively easy and can readily be supported with concrete referents; for example, by twisting a few pieces of rope.

There are broader implications of the large numbers of concrete–symbolic responses for the conduct of practical work. It has been found previously that undergraduate science students who exhibited concrete thinking worked in "descriptive and inductive ways", and argued that that this should be recognised and accommodated by teachers (Shymansky & Yore, 1980, cited in Laws, 1996, p. 18). This contention is supported by the many students in this study who found the practical exercises helpful in improving their understanding of meiosis. Maintaining hands–on practical activities in the learning of tertiary science is crucial, with researchers such as Shymansky and Penick (1979, cited in Laws, 1996, p. 26) claiming that practical work at the introductory level should provide concrete examples to reinforce or introduce concepts raised in lectures, tutorials or textbooks.

The findings from this study, though, also suggest that changing the practicals in the topic and rest of the unit, towards the category of experimental investigations (Hegarty-Hazel et al., 1987) may assist student learning of basic knowledge of meiosis by improving motivation and reducing boredom. The other potential advantage is that it may assist students to develop broader skills of scientific enquiry, which Hegarty-Hazel (1990, p. 365) claimed to have been neglected in favour of a detrimental focus on content in science practicals. There is some tension, and a balance required, between providing explanatory concrete referents and examples and facilitating scientific inquiry and experimentation.

This study supports the conclusion of Hounsell and McCune (2002) that computer aided learning (CAL) could be a valuable alternative to practical work in some situations. Computer aided learning would seem to be particularly beneficial as an addition to the face-to-face practical component for the external students in this study, whose access to real laboratory environments and interaction with staff and students was so restricted. It could also potentially ameliorate some of the boredom of many internal students with the status quo.

Finally, the potential value of changing the broader learning context to be more supportive of deeper approaches, as is argued by many researchers (e.g., Prosser & Trigwell, 1999; Ramsden, 1992), needs to be considered. It is possible that modifications such as a reduced focus on transmission of information, different practical activities and/or assessment incorporating some student choice, and more use of CAL and an interactive learning management system for external students, could be beneficial in fostering more interaction, better engaging students and improving their learning. Changes such as these would certainly be more in line with more student–centred conceptual change models of teaching advocated in tertiary teaching and learning research (e.g., Prosser & Trigwell, 1999, pp. 137-163).

But would such changes to the learning context, desirable though they may be, make any substantial difference to learning approaches or outcomes? A number of studies have suggested that they may not. Cuthbert (2005, p. 246) reviewed three studies suggesting that "favourable" contexts "did not necessarily result in the changes in students' approaches that proponents have suggested". Inducing deep approaches is difficult (Haggis, 2003, p. 92) perhaps because of the profound influence of the students' personal situations and cultural values and other presage factors in the 3P model. Moreover, Prosser and Trigwell (1999, p. 107) suggested that changing the learning context may be insufficient to promote deep approaches because of variations in students' perceptions of their learning situation. As argued by Entwistle and Tait (cited in Entwistle et al., 1991, pp. 249-250), students who have a surface orientation to learning "actively preferred" learning contexts characterised by features conducive to surface learning approaches.

These acknowledged difficulties in inducing deep approaches are supported by the argument of Haggis (2003, p. 98) that students are not passive creatures who can necessarily be moulded to fit with institutional values and goals. There is a limit to which students' perceptions of their learning situation and therefore their learning approach "can be changed by university teachers and administrators", as claimed by Prosser and Trigwell (1999, p. 85). This is certainly not an argument for maintaining the status quo. It merely acknowledges the influence of students' characteristics on their learning, which may limit the effects of varying learning contexts

Implications for theory

This section outlines the contribution of this study to theoretical issues related to students' learning in higher education. The first area considered is learning approaches, in particular the contribution of Rasch measurement modelling and the comparison of internal and external cohorts. In terms of learning outcomes, the implications of the hierarchy of students' understandings of meiosis are outlined. Finally, the implications of the learning approach and outcome relationship in relation to the validity of the SOLO model are discussed.

In terms of learning approaches, this study is the first to apply Rasch measurement modelling to one of the SPQ family of learning approaches questionnaires. This analytic approach proved to be a useful alternative indicator of the validity and reliability of the deep and surface scales of the MSPQ. This form of measurement also provides interval–level linear scales with concomitant advantages in using parametric statistical techniques to analyse quantitative data.

The study also contributed to theoretical understanding of learning approaches, by investigating and comparing the learning approaches of very different cohorts of students enrolled in the same unit. In addition, the broad context and student base for the study is quite different to much comparable research. This further informs the evidence base of the learning approaches model, but questions to some extent its relevance to the population of young students that formed the internal cohort of this study.

A valuable outcome from the study is the establishment of a hierarchy of students' understandings of meiosis that is based on an explicitly articulated theoretical model.

Understanding of the qualitatively different ways in which meiosis is understood by first–year biology students is of value on both practical and theoretical grounds. It also confirms and extends previous work into the areas of confusion surrounding the concept of meiosis, relating difficulties with concepts such as homologues to their degree of abstraction as explicated in the SOLO model. Moreover, this is one of very few studies that have used a qualitative measure of tertiary science students' actual assessment responses in investigating learning outcomes.

This study is the first to use the more recent and complex two-learning-cycle per mode version of the SOLO model in assessing qualitative differences in examination responses in tertiary science, and in investigating the learning approach/outcome relationship. The study therefore represents a relatively valid account of SOLO and the learning approach/outcome nexus in a natural setting. Many aspects of this study therefore contribute to theory by supporting the validity of the SOLO model used. The correlation between SOLO levels and marks for assessment questions supports the criterion validity of the model. The association between predominantly surface approaches with responses to M_2 or below, and deep approaches with responses at or above R_2 is an indicator of the between–construct validity of the model used.

Implications for further research

This section outlines the implications of this study for further research into several areas of first–year science students' learning. The first area of potentially fruitful research is in exploring the lack of difference in the learning outcomes of internal versus external cohorts. The potential for broader comparative research into students' experiences of distance education is outlined, followed by a discussion of the need for separating age and enrolment variables. Some valuable research directions for the SOLO model are raised, including its relation to knowledge objects. Finally, this section highlights some difficulties in the relationship between students' goals and values, and their approaches to learning and constructions of scientific knowledge, that warrant further research.

One area for further research is in comparative studies of the learning outcomes of students in off– and on–campus study modes. This is of particular interest given the findings in this study of no significant difference between outcomes of older external and younger internal students, despite the deeper learning approaches of the external cohort. This issue warrants further investigation, especially as first–year mature–aged students in Australian universities "typically receive higher marks than their younger peers" (Krause et al., 2005, p. v). It would therefore be instructive to investigate further the learning contexts, approaches and outcomes of these two cohorts of students.

A related avenue of future research is to disentangle the age and off– and on–campus variables. Examining learning approaches and outcomes for age–matched internal and external samples could further inform our understanding of differences in how students experience distance versus classroom based learning. Of particular interest is the opportunity to explore these areas further in the context of undergraduate science.

More broadly, there is potential for future comparisons of the broader learning experiences of on– and of– campus students in similar contexts, to inform the burgeoning array of distance education options. Having both cohorts enrolled in single units of study provides a good opportunity for comparative studies of the relative learning experiences of these two different student populations. The necessity for clarifying the relative effectiveness of distance education in terms of content domains, types of learners, pedagogy and media has been argued by Bernard et al. (2004, p. 383), who also highlighted motivational aspects of distance study as a productive direction for future research (p. 415). Comparative research into different models of tertiary science education seems to be of particular value. Web–based science courses with some laboratory component are rare (Davenport, 2001, p. 1620), so exploration of different models of distance science teaching would be a valuable research direction.

The SOLO model used in this study is also a potential area for further research, particularly in its relevance to assessing responses to concepts related to meiosis, or those at different levels in the hierarchy of biological knowledge. Two areas in particular stand out. One is to analyse students' responses to questions about mitosis using the model, and to compare these to the categorisation of responses achieved for meiosis. Mitosis is tightly related to meiosis but conceptually much less complex, and the abstract component of homologues that signified the formal mode in meiosis is largely irrelevant to the process of mitosis. The second area of interest would be to examine the categorisation of responses for questions lower again down the hierarchy about how individual chromosomes reproduce.

Such research could inform the issue of whether there is point at which the complexity of the subject matter limits the utility of the two-cycle version of SOLO. It seems that as the complexity of the concepts increases, so does the complexity of the constituent elements and the relations between them, each of which themselves could be understood by any given individual student at different SOLO levels.

Future research could usefully explore the relationship between the "knowledge objects" which have been identified from phenomenographic research (Entwistle & Marton, 1994), and some aspects of the SOLO model and cognitive science theories. This area seems to represent yet another point of convergence between different research perspectives. The term "knowledge object" was coined from analyses of interview transcripts to describe a form of understanding that is "so tightly integrated that it was experienced as an entity with form and structure" (Entwistle & Marton, 1994, p. 168). As described in Chapter 2, "mental objects" had earlier emerged from a cognitive science research into learning mathematics: "as the procedure is practiced, the procedure itself becomes an entity – it becomes a *thing*. It, itself, is an input or object of scrutiny..." (Davis, 1984, quoted in Tall et al., 2000). The conceptual similarities between the knowledge objects emanating from phenomenography, and the encapsulated "mental objects" which are described in process — object encapsulation theories and explained by the SOLO model warrant further exploration.

In addition, there is much scope for further research into the way that students can be really engaged in learning scientific concepts in the challenging context of introductory biology units, in an era of mass education and ICT possibilities. Although this thesis has highlighted areas of commonality and complementarity from different research perspectives at the broad undergraduate level, there is still much to be clarified within the area of learning science. For instance, it has been argued that that for successful science teaching we must "assume" that students share with scientific practitioners the goal of constructing scientific models.

> Students may not have the same particular goals that scientists try to attain. But, unless we assume that they share, with the inventors and developers of the conceptual models we call science, the goal of constructing a relatively

> reliable and coherent model of their individual experiential worlds, we cannot lead them to expand their understanding. Memorising facts and training in rote procedures cannot achieve this. (von Glasersfeld, 1989, p. 138)

This is in direct opposition to Haggis's (2003, p. 97) contention that we cannot assume that students share the same goals as academics, and that to do so is inappropriate in the new context of current mass university education. On the one hand this conflict highlights the imperative need to foster science students' desire to search for and construct meaning, by ensuring learning contexts are as relevant, engaging, and encouraging of deep learning as possible. On the other hand, though, it perhaps signals a limitation of the extent to which learning approaches and outcomes can be influenced by learning contexts. It seems that a productive area for future research into teaching and learning in undergraduate science is to grapple further with these issues, and how learning approaches theory might be complemented by other perspectives to help students to expand their scientific understandings.

Overview

This study of the learning approaches and outcomes aspects of the 3P model has integrated two major theoretical areas of learning approaches and SOLO assessment of learning outcomes, taking into account recent advances in the SOLO model that have not previously been investigated in relation to learning approaches. It has been conducted amidst the challenges posed by real–life complexities in the natural setting of a first–year introductory biology topic, which was taught across internal and external modes. The results from this study are both internally coherent, and interpretable in the light of previous research. The complementary qualitative and quantitative methods have enabled rigorous cross-checking of findings from different data sources, using a range of very different analytical techniques.

A range of implications for teaching in this and similar learning contexts have emerged from this study. Many of these relate to the potential value in adopting more student–centred conceptual change pedagogy which rewards deep rather than surface approaches. This might involve incorporating more exploratory activities and variety in practicals, some computer–mediated student-student and staff-student interaction for external students, and student choice of activities developed with particular relevance to different degree programs. Such changes to the learning context may not necessarily be successful in large–scale promotion of deep approaches, because of other factors related to students' characteristics. They would, though, be theoretically well–founded, and may address some of the issues relating to students' learning approaches and outcomes that have been raised in this study.

This study has also contributed to theory in several areas. It has applied Rasch measurement modelling to a version of the SPQ for the first time, and highlighted its advantages in evaluating the validity and reliability of the deep and surface scales and establishing interval–level data. The study has established a hierarchy of qualitatively different student understandings of meiosis and related these to areas of confusion and misconceptions. It has supported the criterion and between–construct validity of the most recent version of SOLO, and contributed to theoretical considerations relating to distance models of first–year science teaching.

In addition to its contributions to theory, the study has highlighted potentially fruitful areas of research into student learning in first–year tertiary biology. One major aspect warranting further exploration is the lack of difference in learning outcomes between mature–aged off–campus and younger on–campus students despite the deeper learning approaches of external students. This is a crucial area of research given the increasing demand for distance study and the burgeoning range of study arrangements which blur the boundaries between on–and off–campus study.

Future research into understandings of related scientific concepts using SOLO also has considerable potential in contributing to our understanding of the model as well as students' understandings in science. The points of similarity between SOLO and its related theories, and between SOLO and phenomenographic categories of description and knowledge objects, are of particular interest, demonstrating as they do the converging findings of very disparate research paradigms.

Finally, students' values and goals, in relation to learning approaches and scientific constructions of meaning, remain as complex issues to be explored. All of these research areas can contribute greatly to our understanding of learning in tertiary science, in the context of the diverse, challenging and exciting range of students and pedagogical options in our current tertiary system.

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Appendix A: The process of meiosis

Meiosis is a type of division of plant and animal cell nuclei, which is shown in diagrammatic form in Figure 1.

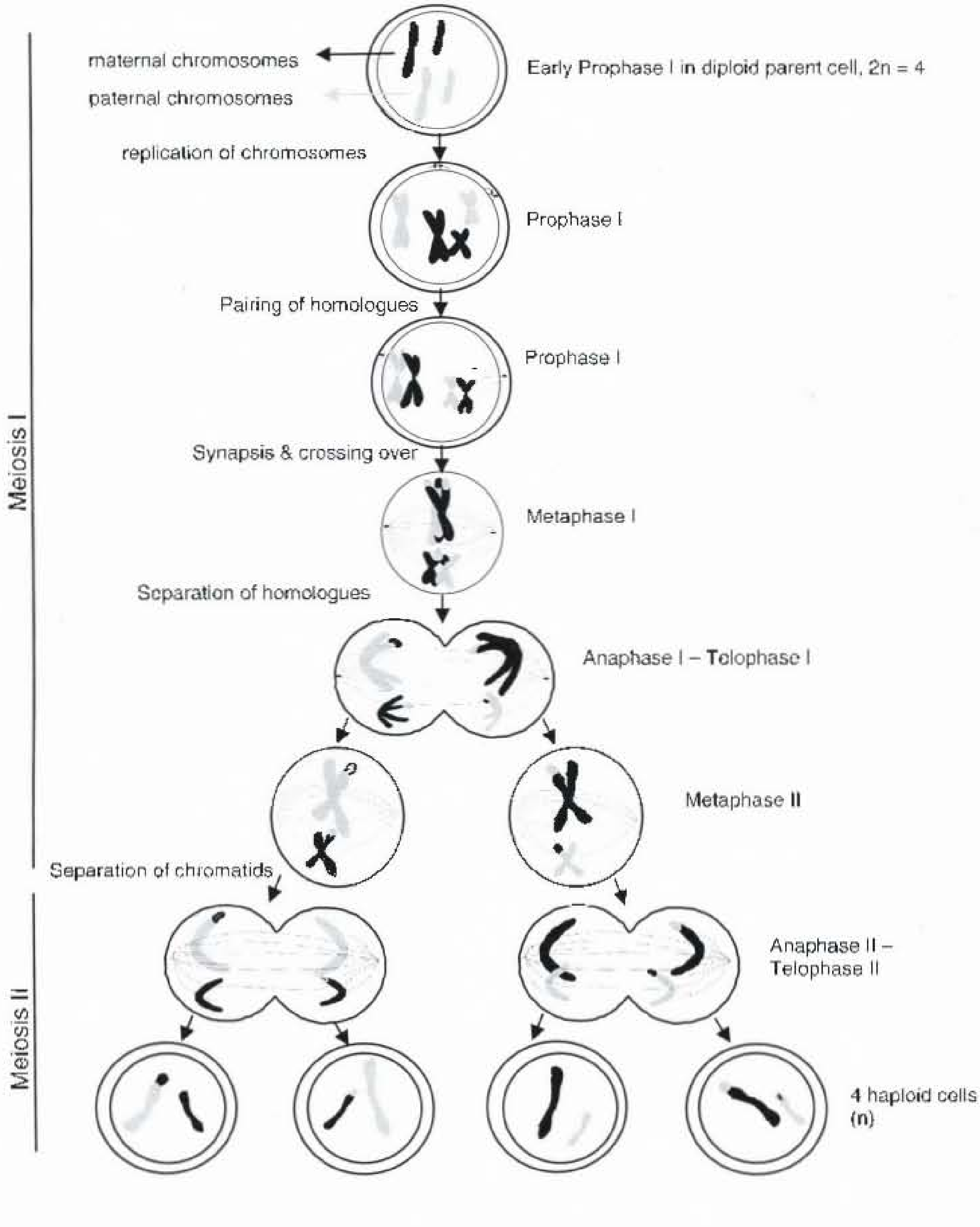

Figure 1: Diagrammatic representation of meiosis (modified from Knox, Ladiges, & Evans, 1994, p. 149).

The following description of meiosis (based on Campbell & Reece, 1999, pp. 236-243; Knox et al., 1994, pp. 149-151) is a simplified account of the major aspects of meiosis, and is not intended to be absolutely comprehensive. Several aspects of meiosis are intentionally left out, including some terms, explanation of the regulatory role of the cyclin – Cdk kinases complex, and differences between plant and animal cells.

Plant and animal cells usually contain two sets of chromosomes in their nuclei; one set inherited from the mother and the other set from the father. These are called diploid cells, and they have a total chromosome number of $2n$, where n is the number of chromosomes in each set. The two sets of chromosomes match, so the total complement of chromosomes consists of a number of pairs of similar, or homologous, chromosomes (homologues), with one of each homologue inherited from each parent. For example, normal human body cells contain two similar Chromosome 21s, one from the father and the other from the mother.

As shown in Figure 1, meiosis halves the number of chromosomes in the nucleus from two sets in the diploid (2n) parent cell to one set in the resulting haploid (n) reproductive cells. This prevents doubling of the chromosome number with subsequent fusion of reproductive cells in fertilisation.

Prior to the first meiotic division, each chromosome replicates, and consists of two identical sister chromatids conjoined at the centromere. In prophase I, the chromosomes (each consisting of two chromatids), condense and shorten, and the homologous chromosomes pair up in synapsis and cross-over. In crossing over, there is a precise exchange of DNA between chromatids of homologous chromosomes, which results in genetic recombination. The physical process of crossing over is controlled by the synaptonemal complex, which is a protein scaffold resulting in alignment and accurate switching of DNA. In prophase I the nuclear membrane breaks down and the spindle of microtubules forms, which physically attaches to the chromosomes and organises and moves them around.

In metaphase I, the homologous chromosomes are attached to the spindle at the kinetochores, and aligned along the central plane of the spindle. In anaphase I the homologues are separated, with one of each pair moving towards opposite poles of the cell. The chromatids of each chromosome, however, remain together. In telophase I the two nuclear membranes reform and daughter cells form. There is random assortment of the homologues during this process, so that the maternally and paternally derived homologues are mixed up in the daughter nuclei. This process halves the chromosome number from $2n$ to n, with the two resulting haploid daughter nuclei each containing only one set (n) of chromosomes. Each of the daughter cells is genetically different from the other, and from the parent cell.

In the second stage of meiosis (Meiosis II), the chromatids of each chromosome are separated in exactly the same way as in mitosis. In prophase II the chromosomes condense, the spindle forms, and the nuclear membrane breaks down. In metaphase II the chromosomes are aligned by the spindle fibres across the equator of the nucleus, and in anaphase II the sister chromatids are separated to opposite poles of the cell. Finally, in Telophase II the nuclear membranes reform and the result is four haploid daughter nuclei. These products of meiosis are reproductive cells. In animals these are the gametes (eggs and sperm), while in plants they are spores.

Appendix B: Information sheet for participants

UNE
The University of
NEW ENGLAND

CRiLT
Centre for Cognition Research
in Learning and Teaching

An investigation into learning, and learning outcomes of tertiary biology students.

19 June 2002

Information Sheet for Students

Doctoral Student: Frances Quinn, PhD Candidate, Teaching and Learning Centre, Tel: (02) 6773 2270

Supervisors: Professor John Pegg. Director, CRiLT, School of Education, UNE, Armidale, NSW. Tel: (02) 6773 5070, Dr. Ted Redden, Head of School, School of Education, UNE. Armidale, NSW. Tel: (02) 6773 5068

Background

This research study is being carried out as part of the requirements of a doctoral thesis, and is primarily concerned with the learning and learning outcomes occurring in first year biology.

There has been a recent and rapid rise in research such as this project, into the interlinked factors of students' prior knowledge, perceptions of their learning situation, approach to learning and learning outcomes, within specific teaching contexts. The anticipated outcomes of this project will include contributions to the knowledge of the learning and teaching process, with specific relevance to students' understanding of tertiary-level biology. These outcomes will potentially better inform the teaching and learning practices currently in use in this subject.

What are the aims of the study?

The main aim of this study is to investigate the learning and learning outcomes in tertiary level biology. The project will focus on one important scientific concept - meiosis - and it is anticipated that the results of this study will shed some light on alternative conceptions in meiosis, the factors influencing student learning and subsequent learning outcomes.

What will be required of the students if they wish to participate in this study?

Participation in this study is entirely voluntary and there will be no penalty for choosing not to. You must also be 18 years of age or older to participate.

It is envisaged that participation will consist of;

- **a questionnaire which contains a number of questions about your attitudes towards the way that you studied meiosis for the last prac test - this will take approximately 10 minutes and will follow completion of a biology topic on Meiosis,**
- **a questionnaire which has a number of questions about your attitudes towards your studies and your usual way of studying - this will take approximately 15 minutes.,**
- **a Questionnaire which asks about your attitudes towards the meiosis section of this course. This will take about 5 minutes and will be administered at the same time as the Study Process Questionnaire.**

- **permission to look at your practical test answers (internals only), examination scripts at the end of semester and access information such as year of birth, enrolment details, final mark for BIOL 120 and grade point average off the student database.**

In addition, you may be requested to participate in

- **a verbal tape recorded face to face or telephone interview following up on certain aspects of your responses to the questionnaires - taking approximately 20 minutes**
- **a focus group interview taking approximately 45 minutes**

Your participation will be limited to these above components and the data gathering will be completed by the end of the academic year 2003. Please note that should you wish to withdraw from any or all of these activities once consent has been given, you will be allowed to do so without penalty.

If you agree to participate in this study, what do you need to do?

If you wish to give consent to participate in this study, please complete the Consent Form attached. Please forward one [1] to myself, Frances Quinn at the address listed on the bottom of this page, and retain one [1] copy for your records. You have the right to withdraw from the project without penalty and at any time.

Privacy and confidentiality

At all times the right of privacy, confidentiality and respect for the participants will be observed. This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No. HEO1/150, Valid to 17/7/04). Data from this study (including tapes and videos) will be stored for 5 years after this study in a locked cabinet and will be destroyed thereafter. Results from this study will be published in a doctoral thesis, and may also be published in scientific journals and conference papers, but there will be no information directly identifying any participant.

Should you have any concerns regarding your academic progress as a result of participation in this project, please contact support services such as the Academic Skills Office (ph. 6773 3600) or Counselling and Careers (6773 2897). If you have any further questions or concerns about this study, you can contact me on the phone number below. Thank you for taking the time to read this information sheet. Participants should retain a copy of the *Information Sheet for Participants.*

Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address:

Research Services, University of New England

Armidale, NSW 2351.

Telephone: (02) 6773 3449 Facsimile (02) 6773 3543 Email: Ethics@metz.une.edu.au

Yours sincerely,

Frances Quinn

(02) 6773 2270

Return Address: Frances Quinn, Teaching and Learning Centre, UNE, Armidale NSW 2351

Appendix C: Consent form

UNE The University of NEW ENGLAND

CRiLT Centre for Cognition Research in Learning and Teaching

An investigation into learning, and learning outcomes of tertiary biology students.

Consent Form for participants
Doctoral Student:

Frances Quinn, PhD Candidate, Teaching and Learning Centre, Tel: (02) 6773 2270

Supervisors:

Professor John Pegg. Director, Centre for Cognition Research in Learning and Teaching, School of Curriculum Studies, UNE, Armidale, NSW. Tel: (02) 6773 5070

Dr. Ted Redden, Head of School, School of Curriculum Studies, UNE. Armidale, NSW. Tel: (02) 6773 5068

Consent

In signing below, I ______________________(insert printed full name) agree that:

- I have read the information contained in the Information Sheet, and any questions I have asked have been answered to my satisfaction. I agree to participate in this study, realising that I may withdraw at any time. I agree that research data gathered for the study may be published, provided that my name is not used.
- I also understand that should any information regarding the study change, so that it differs from the Information Sheet for Participants dated 19 June 2002. I will be provided with an additional Information Sheet containing these details and a reviewed Consent Form for Participants.
- I am over 18 years of age.
- I understand the nature of the research sufficiently well to make a free informed decision.

Signature (______________________________) Date:......................

Please return the signed consent form the address of the doctoral student at the top of this page.

Appendix D: Group interview protocol

Focus group protocol

Preliminaries

1. Introduction of self & others
2. Explanation of what I'm doing
3. Purpose and goal of discussion: your attitudes towards the Cellular and Organismal Reproduction section (remind who & what was done). (not consensus but diversity)
4. My confidentiality assured: their respect for privacy requested
5. Taping

Questions

How interesting and relevant was the section on C&O Reproduction??

How useful were the lectures?

> *What sorts of things about the lectures supported you in your learning?*
>
> *What sorts of things about the lectures didn't support you in your learning?*
>
> *Is there anything you can think of that could have made the lectures better – more relevant or more interesting??*

How useful was the prac?

> *What sorts of things about the prac supported you in your learning?*
>
> *What sorts of things about the prac didn't support you in your learning?*
>
> *Is there anything you can think of that could have made the prac better – more relevant or more interesting??*

How would you compare the roles and usefulness of prac and lectures?

What was most important to you when you went to the lectures and pracs?

What did you think of the amount of content in the section? Its difficulty?

What do you think is the best way to do well in the assessment of this stuff (i.e. in prac tests and exam)

Do you think that students' attitudes make any difference to the way that lecturers and demonstrators go about teaching?

What do you see as the purpose of tertiary education?

Wrap-up

1. Any questions from any one?
2. Reassure re confidentiality etc.
3. Many thanks & best wishes for studies

Appendix E: Individual Interview protocol

E[1] - Internal students

Preliminaries

1. Introduce self again
2. Explanation of what I'm doing
3. Purpose and scope of interview: The combination of your questionnaire & prac responses interesting for what I'm doing, want to ask you a few things about meiosis and the way you approached the work in that part of the unit.
4. Confidentiality assurance
5. Taping
6. If at all stressed by questions, just let me know & we'll stop or move on.
7. Any questions before we start?

Part 1 Meiosis

1 What other units have you done /are you doing

2 Apart from BIOl 120/110, have you heard about meiosis before? When? Context?

Show prac test:

3 **Probe**: if you were doing this again, would you add anything? What?

Ask for clarification of meanings: what do you mean by…? What's the difference between…How does this…? Why does this go here...? etc.

Could you extend answer any further? Explain the process to me (using drawings)?

4 **Prompt** towards next SOLO level: How does this lead to that…? what is this…? focussing questions towards next level.

5 **Re-probe more deeply: Show 3 drawings of chromosome on card**.

A. Unreplicated chromosome

> 5a What is this? What is it made of? Where did it come from?
>
> Where would you find one of these? (Haploid or diploid nuclei?)

B (replicated chromosome)

> 5b What is this? What is it made of? Where did it come from? How come there are two strands? Where would you find one of these? (Haploid or diploid nuclei?)
>
> Alleles: if there was one here, would there be anything over here?

C Homologous pair (in context)

> 5cWhat is this? What is it made of? Where did it come from? How come there are four strands? Where would you find one of these? (Haploid or diploid nuclei?)
>
> Alleles: if there was one here, would there be anything over here?

Part 2 Learning Approaches

1. How interesting to you was the work in this section?
2. How relevant?
3. When you were studying this material, what were you aiming to do?
4. How did you study…what did you do?
5. Understanding vs remembering?
6. Was your study any different for this than other parts of BIOL 120. If so, why?
7. How do you know if you've learned something?

Wrap-up

1. Any questions?
2. Do you want me to explain anything about meiosis?
3. Reassure re confidentiality etc.
4. Many thanks & best wishes for studies

E^2 - External students

Preliminaries

1. Introduce self again and thanks for participating –
2. Is this a good time to ring – should I ring back?
3. Explanation of what I'm doing
4. Purpose and scope of interview: The combination of your questionnaire & question response interesting for what I'm doing, want to ask you a few things about meiosis and the way you approached the work in that part of the unit.
5. Confidentiality assurance
6. Taping
7. If at all stressed by questions, just let me know & we'll stop or move on.
8. Any questions before we start?

Part 1 Meiosis

1 What other units have you done /are you doing

2 Apart from BIOl 120/110, have you heard about meiosis before? When? Context?

Read out answer from question put during res. school:

3 **Probe**: if I were to ask this again, would you add anything? What?

Ask for clarification of meanings: what do you mean by…? What's the difference between…How does this…? Why does this go here...? etc.

Could you extend answer any further? Explain the process to me?

4 **Prompt** towards next SOLO level: How does this lead to that…? what is…? focussing questions towards next level.

Part 2 Learning Approaches

1. How interesting to you was the work in this section?
2. How relevant?
3. When you were studying this material, what were you aiming to do?
4. How did you study…what did you do?
5. Understanding vs remembering?
6. Was your study any different for this than other parts of BIOL 120. If so, why?
7. How do you know if you've learned something?

Wrap-up

1. Any questions?
2. Do you want me to explain anything about meiosis?
3. Reassure re confidentiality etc.
4. Many thanks & best wishes for studies

Appendix F: MSPQ

F[1] - Internal students

Study Process Questionnaire.

Your name...

Section of unit: Cellular & Organismal Reproduction
(Lectures wk 1, practical wk 2, practical test wk 5)

On the following pages are a number of questions about your ways of studying in the section of the unit named above. The following questions have been carefully selected to cover the more important aspects of studying topics such as this.

For each item there is a row of numbers (1-5) corresponding to a five-point scale. A response for an item is shown by circling one of the five numbers. The numbers stand for the following responses:

1. this item was *never* or *only rarely* true of me in this section of the unit.
2. this item was *sometimes* true of me in this section of the unit.
3. this item was true of me about *half the time* in this section of the unit.
4. this item was *frequently* true of me in this section of the unit.
5. this item was *always* or *almost always* true of me in this section of the unit.

Please answer each item. Do not spend a long time on each item: your first reaction is probably the best one. Your answers are CONFIDENTIAL and will not be divulged to anyone teaching in this unit. Thank you for your cooperation.

		Only rarely				Almost always
1	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..............	1	2	3	4	5
2	I find that studying this topic gives me a feeling of deep personal satisfaction..........	1	2	3	4	5
3	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..	1	2	3	4	5
4	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...	1	2	3	4	5
5	I am worried about how my performance in this section will affect my overall assessment..	1	2	3	4	5
6	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..............................	1	2	3	4	5
7	I learn some things by rote, going over and over them until I know them by heart.......	1	2	3	4	5
8	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..	1	2	3	4	5

		Only rarely				Almost always
9	Whether I like it or not, I can see that doing well in this section is a way for me to get a good grade in the unit	1	2	3	4	5
10	I feel that this topic became interesting once I became involved in studying it	1	2	3	4	5
11	In studying this section, I am focussing more on the factual content than the theoretical material	1	2	3	4	5
12	I find that I have to do enough work on this section until I personally understand the material, before I am satisfied	1	2	3	4	5
13	I worry that even if I work hard for this section, the assessment might not reflect this	1	2	3	4	5
14	I find that studying this topic is as interesting as a good novel or movie	1	2	3	4	5
15	I restrict my study to what is specifically set, as I think it is unnecessary to do anything extra	1	2	3	4	5
16	I try to relate what I have learned in this topic to material in other sections	1	2	3	4	5
17	I think it's only worth studying material that I know will be examined	1	2	3	4	5
18	I become increasingly absorbed in my work in this section the more I do	1	2	3	4	5
19	I learn best in this section from teacher(s) who work from carefully prepared notes and outline major points neatly on their whiteboard/slides	1	2	3	4	5
20	I find most aspects of the section interesting and spend extra time trying to obtain more information about them	1	2	3	4	5
21	I almost resent having to study topics like this, but feel that the end results will make it all worthwhile	1	2	3	4	5
22	I believe strongly that my main aim in studying this section is to understand it for my own satisfaction	1	2	3	4	5
23	I find it best to accept the statements and ideas of my teacher(s) and question them only under special circumstances	1	2	3	4	5
24	I spend a lot of free time finding out more about interesting aspects of this topic	1	2	3	4	5
25	I am prepared to work hard in this section, because I feel it will contribute to my employment prospects	1	2	3	4	5
26	Studying in this section has challenged my views on how the world works	1	2	3	4	5
27	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	1	2	3	4	5
28	I try to relate new material, as I am reading it, to what I already know on that topic	1	2	3	4	5

Source: Adopted with kind permission from Michael Prosser, as used in Prosser, Trigwell, Hazel and Gallagher (1994).

F^2 - External students

Study Process Questionnaire.

Your name..

Section of unit: Cellular & Organismal Reproduction

(Lectures 1-3 Study Guide, lecture 1 and prac 1 of res. school)

On the following pages are a number of questions about your ways of studying in the section of the unit named above. The following questions have been carefully selected to cover the more important aspects of studying topics such as this.

For each item there is a row of numbers (1-5) corresponding to a five-point scale. A response for an item is shown by circling one of the five numbers. The numbers stand for the following responses:

1. this item was *never* or *only rarely* true of me in this section of the unit.
2. this item was *sometimes* true of me in this section of the unit.
3. this item was true of me about *half the time* in this section of the unit.
4. this item was *frequently* true of me in this section of the unit.
5. this item was *always* or *almost always* true of me in this section of the unit.

Please answer each item. Do not spend a long time on each item: your first reaction is probably the best one. Your answers are CONFIDENTIAL and will not be divulged to anyone teaching in this unit. Thank you for your cooperation.

		Only rarely				Almost always
1	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..............	1	2	3	4	5
2	I find that studying this topic gives me a feeling of deep personal satisfaction..........	1	2	3	4	5
3	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..	1	2	3	4	5
4	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...	1	2	3	4	5
5	I am worried about how my performance in this section will affect my overall assessment..	1	2	3	4	5
6	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.............................	1	2	3	4	5
7	I learn some things by rote, going over and over them until I know them by heart......	1	2	3	4	5
8	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..	1	2	3	4	5

		Only rarely				Almost always
9	Whether I like it or not, I can see that doing well in this section is a way for me to get a good grade in the unit	1	2	3	4	5
10	I feel that this topic became interesting once I became involved in studying it	1	2	3	4	5
11	In studying this section, I am focussing more on the factual content than the theoretical material	1	2	3	4	5
12	I find that I have to do enough work on this section until I personally understand the material, before I am satisfied	1	2	3	4	5
13	I worry that even if I work hard for this section, the assessment might not reflect this	1	2	3	4	5
14	I find that studying this topic is as interesting as a good novel or movie	1	2	3	4	5
15	I restrict my study to what is specifically set, as I think it is unnecessary to do anything extra	1	2	3	4	5
16	I try to relate what I have learned in this topic to material in other sections	1	2	3	4	5
17	I think it's only worth studying material that I know will be examined	1	2	3	4	5
18	I become increasingly absorbed in my work in this section the more I do	1	2	3	4	5
19	I learn best in this section from teacher(s) who work from carefully prepared notes and outline major points neatly on their whiteboard/slides	1	2	3	4	5
20	I find most aspects of the section interesting and spend extra time trying to obtain more information about them	1	2	3	4	5
21	I almost resent having to study topics like this, but feel that the end results will make it all worthwhile	1	2	3	4	5
22	I believe strongly that my main aim in studying this section is to understand it for my own satisfaction	1	2	3	4	5
23	I find it best to accept the statements and ideas of my teacher(s) and question them only under special circumstances	1	2	3	4	5
24	I spend a lot of free time finding out more about interesting aspects of this topic	1	2	3	4	5
25	I am prepared to work hard in this section, because I feel it will contribute to my employment prospects	1	2	3	4	5
26	Studying in this section has challenged my views on how the world works	1	2	3	4	5
27	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	1	2	3	4	5
28	I try to relate new material, as I am reading it, to what I already know on that topic	1	2	3	4	5

Source: Adopted with kind permission from Michael Prosser, as used in Prosser, Trigwell, Hazel and Gallagher (1994).

Appendix G: MSPQ validity check:

G[1] – Internal students

Your name...

Part A: Below are a few short background questions. Please write your name in the space provided and then indicate whether you agree or disagree with the following statements by circling the appropriate response.

1	I remember the section of the unit on Cellular and Organismal Reproduction (Lectures week 1, practical week 2, practical test week 5)	Agree	Disagree
2	The teaching in the Cellular and Organismal Reproduction section has been typical of the rest of BIOL 120 so far.	Agree	Disagree
3	My approach to study in the Cellular and Organismal Reproduction section has been typical of the rest of BIOL 120 so far.	Agree	Disagree

- If you disagree with items 2 or 3 above, could you please briefly explain how the teaching and/or your study was different.

....
....
....
....

Part B: *Please fill in the following information.*

- Year you last studied biology (excluding this year)......................

2. Indicate the highest level at which you studied biology (excluding BIOL 110 or 120) by ticking the appropriate box

Year 10 science	☐	Year 11/12 2-unit biology	☐
Year 11/12 general science	☐	Year 11/12 3-unit science	☐
Year 11/12 Science for Life	☐	Other (please specify below)	☐

....
....

G² - External students

(part C only included in Year 2 of study)

Your name...

Part A: Below are a few short background questions. Please write your name in the space provided and then indicate whether you agree or disagree with the following statements by circling the appropriate response.

1	I remember the section of the unit on Cellular and Organismal Reproduction (Lectures 1-3 of Study Guide, lecture 1 and practical 1 of residential school)	Agree	Disagree
2	The teaching in the Cellular and Organismal Reproduction section has been typical of the rest of BIOL 120 so far.	Agree	Disagree
3	My approach to study in the Cellular and Organismal Reproduction section has been typical of the rest of BIOL 120 so far.	Agree	Disagree

- If you disagree with items 2 or 3 above, could you please briefly explain how the teaching and/or your study was different.

....
....

....
....

Part B: *Please fill in the following information.*

- Year you last studied biology (excluding this year)......................

3. Indicate the highest level at which you studied biology (excluding BIOL 110 or 120) by ticking the appropriate box

Year 10 science	☐	Year 11/12 2-unit biology	☐
Year 11/12 general science	☐	Year 11/12 3-unit science	☐
Year 11/12 Science for Life	☐	Other (please specify below)	☐

....
....

PTO for Part C

Part C: Describe your understanding of the process of meiosis as fully as you can.

(Without recourse to your notes or textbooks, taking no more than about 5 minutes)

And finally: If you would be prepared for me to ring you to ask you a few questions about your approach to your study and your understanding of meiosis, could you please write your phone number here. ………………………………..

Thankyou very much for your time and best wishes for the rest of the unit, Frances