Enhancing the quality of first-year Biology teaching at the University of Stellenbosch

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

SUMMARY

Transformation in biology teaching is inevitable. There is a global concern about the quality of undergraduate biology teaching, especially when considering the growth in the fields of biotechnology and the molecular sciences. Programmes of learning have to be market orientated, and the contents of curricula have to equip students for entrance into a specific career.

At the University of Stellenbosch the School for Biological Sciences has developed an interdisciplinary approach to first-year biology teaching. The new programmes in Biological Sciences, implemented in 2000, contain first-year curricula that introduce students to the disciplines of genetics, botany, zoology, microbiology, biochemistry and statistics. This involves participation by six departments, and lecture facilitation in two languages for up to 600 students. As contact sessions between lecturers and students are limited, self-study is becoming increasingly important, and lectures should be fully exploited to obtain deep learning. This study investigated various ways to enhance the teaching and learning process for first-year biology students in a module fraught with growing pains and problems.

The influence of software support on student learning was evaluated, while the introduction of an innovative approach to teaching statistics to first-year students was analyzed. Supplementing the statistics section with video-recordings of the lectures was further considered as a possible way of overcoming various obstacles in especially this section of the module. The application of a practical laboratory course to enhance the quality of the theoretical lectures was also investigated and evaluated.

It can be concluded that no simple solution could be found to solve the variety of problems that arose with implementation of the new programmes of learning. Technology proved to be invaluable, but should be applied after thorough needs assessment and impact studies have been performed. Provision of IT tools and facilities do not necessarily imply their application and effect, and innovation and inspiration still proved to be most effective in enhancing biology teaching.

OPSOMMING

Transformasie in biologie-onderrig is onvermydelik. Daar is wêreldwye kommer oor die kwaliteit van voorgraadse biologie-onderrig, veral in die lig van die vooruitgang in biotegnologie en die molekulêre wetenskappe. Programme van onderrig moet markgerig wees, en die inhoud van leerplanne loopbaangerig.

Die Skool vir Biologiese Wetenskappe van die Universiteit van Stellenbosch het sedert sy stigting 'n interdissiplinêre benadering tot eerstejaarsbiologie-onderrig ontwikkel. Die nuwe programme in die Biologiese Wetenskappe wat in 2000 geïmplementeer is, bevat eerstejaarskurrikula wat studente bekendstel aan die dissiplines van genetika, botanie, soölogie, mikrobiologie, biochemie en statistiek. Ses departemente is hierby betrokke, en lesings word in twee tale vir tot 600 studente aangebied. Aangesien kontaksessies tussen dosente en studente beperk is, word selfstudie toenemend belangrik, en lesure moet ten volle benut word om 'n diepgaande leerproses te verkry.

Hierdie studie ondersoek derhalwe verskeie potensiële maniere waarop die onderrig- en leerproses by eerstejaarbiologie-studente versterk kan word.

Die invloed van sagteware-ondersteuning by die leerproses is geëvalueer, terwyl 'n nuwe innoverende benadering tot statistiek-onderrig vir eerstejaarstudente geanaliseer is. Uitbreiding en ondersteuning van die statistiek-seksie, d.m.v. video-opnames van die lesings, is verder oorweeg om verskeie van die hindernisse in veral hierdie deel van die module te oorkom. Die toepassing van 'n laboratoriumkursus om die kwaliteit van die teoretiese lesings uit te brei is ook geëvalueer.

Daar kan saamgevat word dat geen enkelvoudige oplossing bestaan om die verskeidenheid van probleme op te los wat met implementering van die programme ontstaan het nie. Tegnologie is onontbeerlik, maar moet toegepas word nadat behoorlike behoeftebepaling en impakstudies uitgevoer is. Verskaffing van informasietegnologie impliseer nie noodwendig die nodige toepassing en effek nie, en innovasie en inspirasie blyk steeds onontbeerlik te wees om biologie-onderrig uit te brei en te versterk.

for the men in my life

Niels, Dieter, Pierre-Henri, Pierre

you *are* my life

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CHAPTER 1

Introduction

1.1 MOTIVATION

There is a global concern about the quality of undergraduate biology teaching, especially when considering the growth in the fields of biotechnology and the molecular sciences (Lord 1998, 2001). According to Marocco (2000) the transformation in the way we view biology can indeed be described as a 'revolution'. In the USA it has recently been found that students often lack a basic knowledge of science (Doyle 2001), and that even graduating students are unprepared to make informed decisions about science-based issues, ranging from health and nutrition to environmental pollution, to national defense (Ogens & Koker 1995). This eventually impacts on productivity growth, and demands from us to take a stringent look at our quality of teaching.

At the University of Stellenbosch the School for Biological Sciences has developed an interdisciplinary approach to first-year biology teaching since its establishment in 1998. The new programmes in Biological Sciences implemented in 2000 contain first-year curricula that introduce students to the disciplines of genetics, zoology, botany, microbiology, biochemistry and statistics. Programmes are market-orientated, and modules are combined to equip students for entrance into a specific career.

As all students in the Biological Sciences programmes of the BSc degree, all BSc Agric, BSc Food Science and BSc Consumer Science, as well as students in Human Movement Science and in some programmes in the Physical Sciences follow the same module Biology 124 during their first semester of first-year studies, classes are facilitated for up to 600 students. Lectures are both in Afrikaans and English, and facilitated by six different departments (Botany, Zoology, Microbiology, Genetics, Biochemistry and Nature Conservation). Contact sessions with the students vary from four to seven lectures per discipline, and much of the information is given as 'core notes'. Self-study by the students become more and more important, and the limited contact sessions with the students should be utilized and exploited to their full potential to obtain deep learning (Entwistle 1999, Biggs 1999). This implies that students will be challenged to actively transform concepts and information in relation to previous knowledge and experience. They will have to be fully engaged in their own learning without the luxury of a benevolent lecturer guiding them all the way.

Furthermore, with the focus on transformation processes in South Africa, and the new 'programme-based approach' expected of higher education (DoE 1997), universities from abroad have recently made inquiry into the approach to developing new programmes and curricula in the Biological Sciences at the University if Stellenbosch. The University of West Georgia (e.g.) has targeted South Africa to introduce a new exchange scheme, involving both students and staff (Stewart 2001).

With the spotlight on South Africa, and the way biology is currently taught, it has become time to evaluate the performance and practices of biology teachers as facilitators of deep and lasting learning. Furthermore, with the specific problems attended with the introduction of the new interdisciplinary biology curricula at the University of Stellenbosch, various ways are investigated in this study to enhance the teaching and learning process for first-year biology students.

1.2 ORGANISATION OF THE RESEARCH

The organisation of the research project was based on the following four steps, followed consistently throughout the processes of investigation, evaluation and analysis described in the study:

- Step 1: Identification of specific problems experienced in the facilitation of learning in the first-year module Biology 124.

- Step 2: Carrying out an extensive literature search on similar case studies grounded in the same paradigm, and with a similar philosophical approach, thereby providing possible solutions to the above-mentioned problems.
- Step 3: Application of questionnaires to obtain student feedback on their qualitative and quantitative experiences in learning while following the module Biology 124.
- Step 4: Integration of the data provided by student feedback with the findings from the literature, as well as personal communications and practical experience, to provide feasible solutions or applicable recommendations to the area of concern.

The following aspects were included in the organisation of this study:

1.2.1 A critical evaluation of the new programmes of learning in the biological sciences at the University of Stellenbosch. Since 2000 a new interdisciplinary first-year curriculum for BSc students in the Biological Sciences have presented those involved in facilitation and administration of the curriculum with many unforeseen problems and obstacles.

1.2.2 An evaluation of the influence of software support on student learning. Inclusion of a CD-ROM with the student edition of the prescribed Biology textbook (Raven & Johnson 2000) provides the student with a means to facilitate self-study, and to enhance the study material, while also promoting active learning.

1.2.3 An introduction of a new and innovative approach to teaching statistics to first-year biology students, with the potential of enhancing their knowledge of the scientific process, and introducing them to the way in which biology is "done". The various problems experienced especially with this part of the module, and the specific procedures followed to overcome them, were analysed.

1.2.4 Supplementing and enhancing the above-mentioned statistics part of the module with video recordings of the lectures and practical sessions. This was carried out by the development of a self-study guide, e.g. for students repeating the course and not attending lectures, as well as for students having problems with lectures in their second language. The self-study guide could present a way to overcome these and other obstacles.

It also served as a pilot investigation into the feasibility of providing students with video recordings of current lectures, thereby addressing the existing problem about a shortage of lecture halls suitable for teaching large classes. At present every lecture in this module has to be repeated three times, leading to an overburdening of the teaching load of lecturers. Valuable hours that could have been invested in contact sessions with students experiencing problems, or in doing research, currently have to be spent repeating the same lecture on different occasions. Such video recordings can be developed to be accessible on the university's intranet on Web-CT. Unfortunately the storage server capacity of the University of Stellenbosch at this stage does not allow such large files to be accessed on the intranet. A campus like the University of California (Monterey), with a storage server capacity of 12 terrabyte, exploits this video-lecturing facility to the advantage of both students and staff.

1.2.5 The application of a practical laboratory course enhancing the quality of theoretical lectures was investigated by application of a questionnaire, as well as a literature study on this aspect of biology teaching. The problems surrounding the assessment of practical sessions, and how assessment can be applied to the advantage of the learning process, was evaluated from the students' response to the questionnaire, and correlated with findings from the literature. Attainment of deeper learning, as well as application of the correct assessment methods to that effect, was thereby investigated.

1.3 RESEARCH METHODOLOGY

1.3.1 Approach

A post-positivist approach was followed throughout the study. Research was carried out within a paradigm of interpretivism, but also included elements of a critical scientific approach. Analysis, evaluation and critique had a practical focal point, and recommendations and tools with practical application were provided. With an interpretive approach to the problem under investigation, understanding was grounded in interactive, field-based inductive methodology, which was embedded in practice and within context.

In order to regard the research as being situated partly in the paradigm of critical science, the rationale was as follows: The knowledge generated by the results to this research was practical, action-orientated and enlightening. Thereby it catalysed change in facilitation and learning. Inquiry was directed at both understanding and practical transformation of academic facilitation conditions and practices necessary for enhancement of teaching and learning . The focus of change in this study was therefore not explicitly socially and politically, and the transformation not directly towards emancipation and empowerment. However, the researcher in this case felt that emancipation and empowerment can be attained equally through a transformation of academic practices in the sciences as by social and political change. This view is also shared by other well-known scientists, including Carl Sagan, who believed that "a familiarity with science techniques and critical thinking is a key ingredient in a participatory democracy" (Ogens & Koker, 1995). According to Morrison (1998) a democracy can hope for wide and informed consent only if that special experience and knowledge (of the specialist/ scientist) is also opened widely at entry level.

I have therefore come to the conclusion that the research can be categorized not only in the paradigm of interpretivism, but with inclusion of some of the criteria of critical science. To be a "straddler of paradigms" (Nduna 2000) may be a predicament more often encountered than expected.

1.3.2 Strategy

The research strategy applied was the use of a case study, focusing on the first-year module Biology 124. As described by Denscombe (1998) a case study should focus on one or more instances of a particular phenomenon, thereby providing an in-depth account of events, relationships, experiences or processes occurring in a specific instance.

In this case study the spotlight fell on a few 'instances' of the obstacles encountered, the learning provided, and probable techniques to be applied in enhancing the new interdisciplinary first-year module Biology 124. An in-depth study was both the aim and the result of the research, focusing on various aspects of a single first-year module. The focus was on relationships and processes within the specific programme of the BSc in Biological Sciences. Although isolated factors were dealt with, the insight gained from the process and experience could be applied holistically to enhance both the facilitation and learning processes. The case study furthermore involved a natural setting, with not a single aspect generated specifically for the purpose of the research. Finally, multiple sources and methods were used in the investigation. Various types of data, both quantitative and qualitative, were dealt with.

1.3.3 Generation and analysis of data

Data on three of the aspects investigated in this study was generated by questionnaire. The impact of software support on student learning (Chapter 3), the effect of a new approach to teaching statistics to first-year biology students (Chapter 4), as well as the approach to assessment of pratical sessions in first-year biology (Chapter 5) were ascertained from the students' response to the questionnaire.

A single questionnaire (see Addendum 1), dealing with all three issues in three separate sections, was compiled by the researcher and completed by all students attending the practical sessions during a typical lecture week at the end of the first semester of 2001. The first section focused on the evaluation of the CD-ROM supplied with the textbook Biology (Raven & Johnson 1999). In this section the students also provided me with biographical data on gender, test marks and BSc programme followed. The second section dealt with the practical course which formed an integrated part of the module Biology 124. Feedback was mostly qualitative in nature. In the final part of the questionnaire the section *How do we do Biology?* was explored with questions focusing on specific points of concern and problem areas identified in this section of the module.

It can therefore be considered that the tripartite questionnaire was developed as the main instrument for generation of data. It was neither compiled from existing questionnaires, nor copied from the literature. The practical considerations taken into account focused on the problems to which solutions were being sought, and questions were formulated accordingly.

More qualitative data on innovative ways of enhancing biology teaching was collected by personal communication locally and abroad, and by personal experience in dealing with the facilitation of the practical sessions to the first-year biology students. Contact was established by personal visits, as well as via e-mail, with Prof. Greg Stewart (2001) from the University of West Georgia, who led a team of Higher Education experts for the Higher Education Council as part of a People to People Ambassador's visit to South Africa.

Video-recordings using a digital video camera were made of the statistics lectures and practical sessions facilitated to the first-year biology students during 2001. After editing of the video material the recordings were incorporated into a self-study package. A DVD (Digital Video Disc) is provided with the final product, and is included in this thesis (see back cover).

Standard software programmes were applied for statistical analysis and graphic presentation of the data.

1.4 SCOPE AND FOCUS GROUP OF RESEARCH

The research dealt exclusively with the 2001 group of first-year biology students enrolled in the module Biology 124. Since the implementation of the new programmes of learning at the School for Biological Sciences the module has been fraught with growing pains, and adapted on a yearly basis. As coordinator of the practical first-year biology programme in 2001 I was directly involved in finding solutions to various problems and obstacles. Firstly, the practical programme in which I was involved was regarded as almost impossible to be implemented with 600 students, considering the available resources. Furthermore, after much debate, the section *How do we do Biology* was introduced to the module in 2001, and software support was for the first time included in the prescribed textbook. In 2001 I was challenged by the prospect of "making things possible", thereby attempting with the rest of the academic team to bring order, stability and excellence to a novel module.

1.5 FORMAT OF THESIS

The thesis is presented as an integrated set of publishable papers. Each chapter therefore consists of an introduction, materials/methods, discussion of results, conclusions and bibliography. The five individual, but related, papers are concluded with a summative discussion on the implications for enhancing quality in first-year biology teaching at the University of Stellenbosch. Overlapping does occur. However, with the various audiences interested in the different topics, and the variety of journals in which the papers (or "thesis chapters") are to be published, it was nevertheless considered to be the most suitable way to present the content of this thesis.

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CHAPTER 2

An interdisciplinary first-year curriculum in the Biological Sciences : Programme development and Biology 124 in perspective

2.1 HISTORICAL OVERVIEW

In January 1995 president Nelson Mandela announced the National Commission on Higher Education (NCHE) who, in August 1996, brought out a framework for the transformation of Higher Education in South Africa in the so-called "Reddy Report" (NCHE 1996). The South African education system, which for years had been in need of transformation, would immediately be subject to change (Lehoko 1998).

In December 1996 the Green Paper on Higher Education and Transformation formulated the Department of Education's policy framework for Higher Education (DoE 1996). This was followed in April 1997 by a Draft White Paper on Higher Education, and in August 1997 by the Education White Paper 3 : A programme for Higher Education Transformation (DoE 1997a). On 19 December 1997 the Higher Education Act was promulgated. This law, together with the Education White Paper 3, outline the four main areas of immediate priority to the Department of Education. These are

(1) the size of the higher education system as a whole,
(2) equal opportunities,
(3) effectiveness and
(4) collaboration

The so-called "Size-and-Shape" document (CHE 2000) and the recent Report of the Minister of Education (Asmal 2001) led to more and extensive in-depth discussion.

In their report the NCHE (1996) identified the following aims:

(1) a single coordinated system of Higher Education should be established to include universities, technikons and colleges,

(2) distance learning and lifelong learning should be exploited to promote access to higher education,
(3) universities should develop their qualifications according to the National Qualifications Framework,
(4) cooperation should be developed on system, area and institutional level,
(5) a new framework for funding was suggested.

Transformation in higher education in South Africa has been influenced greatly by international changes in education. After rejoining the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in 1994 the international influence on the formation of policy, vision and strategy in education has been apparent (Charles 1997). The new focus on learner centred education, outcomes-based teaching and teaching programmes is part of the internationalisation of universities worldwide. In South Africa the stress on internationalising the teaching programmes is to provide the country with skills that will enable it to compete in the global economy (Monyokolo & Potenza 1997).

At the University of Stellenbosch (US) the interpretation of the various above-mentioned documents on education, as well as influential international documents, led in March 1998 to the announcement of its own official document, the US Academic Planning Framework (US se Akademiese Beplanningsraamwerk) (Council of the University of Stellenbosch 1998). In this document the US specifies its policy framework for all academic activities within the new Higher Education system.

In 1998 the Council on Higher Education (CHE) was established to advise the Ministry of Education on aspects of higher education, to establish and maintain a permanent Higher Education Quality Committee (HEQC), and to promote access to higher education. The task of the HEQC is to coordinate quality assurance in higher education, and to accredit programmes in higher education. Furthermore a body, the National Qualifications Framework (NQF), was established by the government to create national standards of education and training. According to McLean (1998) the NQF is the mechanism which government has proposed to deal with problems of :

(1) linkages between different areas of education, training and development,
(2) to promote increased quality learning, which is more relevant to individual and national needs, and
(3) to redress previous discrimination against people.
In other words, the flexibility of the education system should allow learners of all ages to enter and exit the learning system by providing for multiple modes of assessment and accreditation in an ongoing process of lifelong learning (MacFarlane & Daniels 2001). According to Kraak (1998) the NQF levels should indicate increasing complexity in learning, and facilitate meaningful progression routes along career and learning pathways.

In 1995 a body called the South African Qualifications Authority (SAQA) was established to oversee the whole process of development and implementation of these NQF standards. The entire University sector has only one representative on this council.

In March 1998 SAQA announced that all qualifications should in the future be accredited by SAQA. By June 1998 all University qualifications had to be registered with SAQA (SAQA 1998). This implied scrutinizing investigation into each qualification via a so-called Standards Generating Body (SGB), which was responsible for recommendation of the qualification to a National Standards Body (NSB), which reported to SAQA. In this way the NSBs were responsible for investigating what changes had to be made in each of the eight levels of learning recognized by the NQF (with qualifications from levels five to eight offered by Universities). A relevant NSB was appointed for each of the 12 fields of the NQF (Gevers 1999). The NSBs would also begin a dialogue between all major stakeholders over what should be taught in the different institutes of learning.

After the NSBs have reached agreement on the standards of qualifications the Education, Training and Quality Assurers (ETQAs) would be responsible for assuring the quality of the outcomes, thereby overseeing the implementation of the standards. New qualifications would in the future only be issued once the new standards have been met (McLean 1998).

However, the first real test for education and training providers lies in turning these new ideas and concepts into learning programmes appropriate to the needs of our country (Monyokolo & Potenza 1997). The challenge furthermore lies in the integration of local and global, and in this the task facing South Africa is complex and challenging (Charles 1997).

2.2 PROGRAMME DEVELOPMENT AT THE UNIVERSITY OF STELLENBOSCH

After the announcement by the Council on Higher Education (1997) that the new approach in higher education would be characterised as a 'programme-based approach', the Council of the Faculty of Natural Sciences immediately opened discussion concerning the approach to this new challenge. Different criteria for the development of programmes were stipulated, and it was emphasized that although the introduction of programmes was enforced by government, it could be developed and applied to the advantage of all courses offered by the university.

The main driving-force in the development of such a programme-based education can be summarized as being (1) accessibility to all learners, (2)national and international competitiveness of all qualifications, and (3)integration of theory and practice (Minutes of the special meeting of the Council for the Faculty of Natural Sciences: 17-04-97).

There should be multiple entry and exit levels for learners in the eight levels of education, and the basic principles applied in the new system of education should be integration, relevance, credibility, coherence, flexibility, standards, legitimacy, access, articulation, progression, transferability, and recognition of prior learning (Uni-Ed 1998). Taking these as intrinsic criteria, new programmes were developed and existing ones adapted, with inclusion of the required generic skills as specified in the SAQA regulations.

At the University of Stellenbosch a format was developed according to which all programmes were developed before submission to SAQA. The so-called 'Claassen' format allowed the development of the required programmes in coherence with the university's own needs, while at the same time complying with the requirements set by SAQA. It also provided the faculty members involved with a protocol for a standardised description of the way in which the programmes satisfied the required conditions and criteria set by the NQF. The Faculty of Science was therefore advised to develop all their programmes with the following criteria as guideline: programmes should be (1) built on identified strong-points, (2) coherent, (3) flexible, (4) marketable, (5) disciplinary or interdisciplinary, and (6) undergraduate programmes should lead vertically to post-graduate programmes (Minutes of the special meeting of the Council for the Faculty of Natural Sciences: 17-04-97). It was emphasized that although the entire project was required by government, it should be accomplished to the benefit of the whole curriculum proposal.

The next crucial step was to define what a 'programme' is, as the 'programme-based approach' expected in the White Paper on Higher Education (DoE 1997a), is not explicitly defined. According to Botha (1997) the various compact characterizations of programmes avoid particulars, thereby veiling much important information. In short it can be defined as 'the sequential learning activities leading to the award of particular qualifications' (DoE 1997a). In more descriptive terms this means that the teaching/learning activity (or 'programme') has a specific, identifiable field of specialisation which may be offered at one or more qualification level and which leads to the award of a qualification at certificate, diploma or degree level. In even more compact terms it is 'a teaching/learning activity which has a specific, identifiable field of specialisation which may be offered at one or more qualification level' (DoE 1997b). In a broad concept different qualifications can be obtained in a single programme. Because focus and coherence are two of the main considerations in the design and evaluation of programmes, the US prefers to use the narrow concept in which every qualification is contained in a separate programme (Uni-Ed 1998).

2.2.1 Programmes in Biological Sciences (with emphasis on Molecular and Cellular Biology).

In the Faculty of Science this transformation process included some fundamental changes in the traditional modus operandi. Firstly the structure of the BSc degree was changed from a 4:3:2 approach to courses in the different years of study to a 4:4:4 structure with four subjects being followed in each year of study. Secondly every subject offered, i.e. every module facilitated by every department involved, would be fit into a specific programme, or stream within a programme. It would therefore no longer be possible to do a general BSc(General) degree, but only one in either Biological Sciences, Physical Sciences or Mathematical Sciences. A few additional programmes were developed, each with its own unique content, e.g. in Consumer Science and Applied Geo-informatics, as well as a BSc with Engineering subjects, BScEd, BScAgric and a BScForestry. All these programmes have a specific career focus, and in this way the marketability of the degree would be greatly enhanced. This will then reflect on the employability of graduates (Preece 1999).

In the BSc in Biological Sciences four different programmes were identified and developed. These include the programmes in (1) Molecular and Cellular Biology, (2) Biodiversity and Ecology, (3) Biotechnology and (4) Human and Life Sciences. Most of the subjects offered in the programmes already existed, and the various modules were developed and adapted to make the programmes flexible, coherent and relevant.

Relevance of the curriculum is often mentioned as a significant criterion (Price 1999, Byett 1999, Fourie & Hay 2000). It is not always possible to make science culturally and politically relevant, although the new first-year course in the philosophy of scientific methods (part of Biology 124) did touch on this issue. Scientific relevance is strived for at all costs, and as a result curricula are constantly changing to keep up with international developments and market expectations. However, it is not clear whether there is an exact indication as to what extent the South African market will become saturated with the great number of graduates in Biological Sciences. Coinciding with the global increase in the demand for cellular and molecular biologists classes in some departments at the University of Stellenbosch (biochemistry and microbiology) doubled in size in the past 6 to 7 years. Such numbers seem to indicate that Asmal's call (2001) for a higher percentage of Science graduates might still be answered.

One major transformation in the new approach to the BSc programmes was the development of an interdisciplinary first-year curriculum for all students in the Biological Sciences. This implies that all students in the four Biological Sciences programmes, as well as the BScAgric and BScForestry students, together with students from one stream in the Physical Sciences programme, follow the same modules in Chemistry, Physics, Mathematics and Biology. In this way the first year of the BSc programme is devoted to building a foundation of knowledge and skills. In the second year the student selects a programme for further study, and in the third year a specific stream is selected within this programme. Flexibility is greatly enhanced in this way, as students can make choices until their final BSc year. Furthermore, as there are great coherence and collaboration among the different Biological programmes, especially Biotechnology and Molecular and Cellular Biology (who in effect share a second-year curriculum), little additional work is necessary if a student changes to another stream of a Biological Sciences programme.

Students who were academically disadvantaged at school are offered the possibility of building their 'first-year foundation' over two years. Access was therefore greatly enhanced by the establishment of the Division for Academic Development Programmes (DADP) (see www.sun.ac.za/dadp/fprog.html) who offers so-called Foundation Programmes and Bridging Programmes. Students from historically disadvantaged communities, who have the necessary potential for university study, but do not meet the requirements for a BSc degree, are recruited for the DADP. After a four week Bridging Programme in Mathematics and Science (with additional focus on language proficiency in Afrikaans and English, Study and Thinking Skills and Computer Literacy) students are evaluated and admitted to a BSc programme provided they follow the four-year ADP route. Students who struggle to keep up with the pace of a scientific curriculum after coming from a disadvantaged position are also encouraged to follow the ADP route of the BSc programme. The whole issue of the implementation of a policy regarding access is investigated in detail by Griessel (2000).

In the development of generic skills as required by SAQA two matters were investigateed at the US : communication skills and technological (computer-) skills. As the skilfull manipulation of information technology is now generally regarded as essential for the 21st century (Preece 1999), all BSc students follow a compulsory computer literacy course until their third year of study. In this way all students can be expected to do assignments, tutorials and general studying with the aid of multimedia and information technology. Other generic or 'critical cross-field outcomes' specified by SAQA are not addressed in the same way, i.e. by addition of an extra module into the programme. However, the facilitation of the various modules of the BSc in Biological Sciences give ample opportunity and scope for the implementation of such generic skills (1-8).

The outcomes of (1) identification and solving of problems, as well as (2) collaboration with other people in a team, are developed from a first-year level in especially the practical courses in the Biological Sciences. (3) Self-management will implicitly be developed by the successful student, while the repetition and dropout cases might very well be ascribed to a lack of this skill. Students arrive at university from a 'spoon-feeding' environment, and they are forced into self-management in the performance of the specific assignments given to them. With the large class-groups characteristic of the new programmes this skill becomes a necessity. The same applies to (4) the collection and manipulation of data. First-year students are overwhelmed by the magnitude of the information handed out to them, discussed in class, and even the thickness of the textbook. In cases where lecturers do not hand out any class notes, and students have to rely merely on the textbook, they often show a lack of critical information manipulation. Lecturers are not always sensitive to the need to develop this skill rather than to implicitly expect students to apply the skill!

The necessary (5) communication skills are hard to develop in the large first-year groups. However, in their third year of study all Biological Sciences students get assignments for written and oral presentation. Communication is a bigger problem in cases where Afrikaans is not the first language, but second or third, and the alternative English is also the student's second or third language. Language efficiency courses are offered by the DADP Programmes, and students are encouraged to attend these.

The development of (6) a holistic approach to global matters is mostly attained in time, as the student obtains perspective of his/her study material. Because science is such a global communication medium, with international concerns of genetics, microbiology and biotechnology (e.g.) being addressed at least from second-year level, this skill does get the opportunity to be developed.

Finally the contribution of the programme to (7) self development is hard to determine. Reflection addressed in the completion of questionnaires on course presentation and content. Other cultural, national, social, market and entrepreneurial contexts are not addressed at the moment.

All four Biological Science programmes are offered by the School for Biological Sciences, which includes the Departments of Biochemistry, Genetics, Microbiology, Botany, Zoology, Physiology and Entomology. The School for Biological Sciences was established in 1998 and gives structure to interfaculty and interdepartmental coordination as it contains departments from the Faculty of Natural Sciences, as well as the Faculty of Agricultural and Forestry Sciences.

Another characteristic of a programme which meets both national and international demands, is that it should be learner-centred, experiential and outcomes-oriented (Gevers 1999). This will also comply with the criteria for success in the new paradigm for undergraduate teaching outlined by Barr & Tagg (1995). Following Arjun's (1998) line of thought, and using the characteristics of Kuhn (1970) and Lincoln (1985), the new ideas and practices of the Biology programmes do not represent a paradigm shift, although they do contain elements of a new learning paradigm as opposed to the old instruction paradigm. This is especially valid for the interdisciplinary first-year curriculum in Biological Sciences.

The criteria for success in the learning paradigm (Barr & Tagg 1995) are mostly in accordance with views on the importance of quality, efficiency and learning of the exiting students and the quantity and quality of outcomes in the Biological Sciences. A holistic approach has been applied in all the programmes offered by the School for Biological Sciences, especially in the first-year Biology curriculum. However, the teaching/learning structures are very much in line with the instruction paradigm, i.e. with 50 minute lectures, fixed time, assessment and grading. It is actually only in the practical sections of the various modules that different learning experiences, the importance of knowledge and skills, cooperative and supportive learning, and the design of the learning environments become implemented. However, practical sessions are compulsory in science training, and have always been. It did not need a paradigm shift to implement, but probably only to define and describe it.

The way in which assessment is carried out is more important than often acknowledged. According to Goodlad (1995) there continues to be much debate about what should be assessed and how. In Barr and Tagg (1995) and Kraak (1998) assessment is emphasized to be ideally continuous (on an ongoing basis) as opposed to the traditional end-of-year assessment leading to exam-driven education and learning. With continuous assessment the outcome of knowledgeable and skilled learners, with both practical and foundational competence (Kraak 1998; McLean 1998), should more readily be attainable. Biochemistry, Chemistry and Mathematics are a few of the departments in the Faculty of Science that have applied the method of continuous assessment, with positive results. In the first-year curriculum both the departments of Chemistry and Mathematics have applied continuous assessment, mainly by the application of available computer networks, software and trained staff! In the Biology modules, being facilitated by six different departments, all efforts to continuous assessment have failed to date, mainly because of the vast number of students involved, the short time that every department is involved with the module, and probably a lack of motivation by the staff.

At least one issue of concern arose in the application of the 'learning paradigm' as described by Barr and Tagg (1995). With the creation of a powerful learning environment in which the student can discover and construct his/her own knowledge it was evident that students are not always receptive to the benefits of such an environment, and the ideological surroundings, expertise and support often pass them by without them filtering out the essence and opportunity for learning. Today's students still grew up in the 'instruction paradigm', and to benefit from a new paradigm of education might be an evolutionary process of which the true effect will only be seen in the future.

The Biological Sciences programmes are ideally constructed to address all three dimensions of competence as outlined by McLean (1998) and Kraak (1998). In all modules and on all levels of working towards a scientific degree foundational competence is facilitated in the lecture halls, and practical competence in the laboratories. Reflexive competence will probably be attained on levels higher than first-year, where classes get smaller, personal contact with the lecturer increases, and the contents of modules become more focused. But even in the first-year biology module the strive is to integrate knowledge and skill, and give the student a sense of knowing it.

Because programmes in Biological Sciences were developed according to the Claassen format, which closely follow NQF requirements, the programmes theoretically withstand scrutinizing critique. However, the finer details reveal a few cracks in the armature, which are mostly concerned with practical implications resulting from the logistics of making the new programmes work.

The application of the new fundamental interdisciplinary first-year curriculum for all the Biological Sciences, with collaboration on both departmental and faculty level, resulted in such a growth in first-year student numbers per lecture that the size of lecture halls, means and frequency of assessment, personal contact with students and the work load of academic and administrative staff were markedly affected.

Furthermore, the amalgamation of the faculties of Agriculture and Forestry, and the interfaculty collaboration in the first-year curriculum, had major implications on the language of instruction. As the US is the only university offering a degree course in Forestry in South Africa, many students of which Afrikaans is not the mother tongue are registered for the course. These students receive obligatory instruction in English. However, many other students who are also more fluent in English started attending the same classes, leading to a marked increase in the need for English lectures. The Faculty of Science resultantly devised a 'language-friendly' approach to the course, with lectures being facilitated in both Afrikaans and English – at least on first-year level, but in many cases also on higher levels. This had major staff implications, as all lecture groups were now split in two, and sometimes even three, with a need for at least two lecture halls being facilitated simultaneously. Even the timetable for first-year students became a major headache!

The available infrastructure was also involved in the application of the new Science programmes. Apart from the larger and more lecture halls needed as described above, the available laboratories also had to be upgraded and adapted for first-year practical work. As microbiology, genetics and biochemistry had never before been instructed on a first-year level, and was only since 2000 involved in the interdisciplinary first-year curriculum, laboratories were totally under-equipped and in some aspects unsuited for the large groups of students and the type of practical work involved. Adapted laboratories, more equipment, and more staff all have financial implications, which often is the final hurdle in the quality race.

2.2.2 Programme Assessment Criteria for the BSc in Biological Sciences .

This section will focus on the BSc in Cellular and Molecular Sciences, with special emphasis on the interdisciplinary first-year curriculum.

2.2.2.1 Programme relevance

In linking the programme's objectives, content and methodology with the requirements of (a) the labour market and higher education community, (b) society and (c) the student, it is imperative to ascertain what these requirements are.

In the development of the programmes in Biological Sciences inquiry was made into other universities' programmes and approach. Locally information was obtained from UCT (University of Cape Town), WITS (University of the Witwatersrand) and the University of the North. International communication was initiated with the School of Biological Sciences in Norwich, the Cold Springs Harbor Laboratory in the USA, Murdoch University in Perth, Australia, and Imperial College, London. The programmes were subsequently developed to be relevant to both national and international requirements for scientists in the biological disciplines.

There is a global concern about the quality of undergraduate Biology teaching, especially when considering the growth in the fields of biotechnology and the biological sciences. With the focus on transformation processes in South Africa, universities from abroad have also made inquiry into our approach to the new programmes. The University of West Georgia (e.g.) has targeted South Africa to introduce a new exchange scheme (Stewart 2001), involving both students and academic staff.

Considering that the programmes in Biological Sciences were only started in 2000, it has not statistically been proven if the needs of the labour market have been met. Given the expertise available and involved in the training of the young scientists, it seems improbable - at least qualitatively - that it should not be met.

In determining the society's general expectations of a biological scientist, it is unknown whether society even has an indication of what is implied by the term 'biotechnologist' or 'microbiologist'. With the recent focus on the human genome project and possible human cloning (Gibbs 2001), the problems with antibiotics (Nicolau & Boddy 2001) and life on Mars (Newcott 1998) biological sciences have been brought into the living rooms of middleclass families. However, expectations by society of a biological scientist may not differ from those for any university graduate – and in that the facilitation of the programme is well-suited. A critical mind, communication and social skills and an openness to diversity are developed in completion of assignments and exposure to international periodicals from the second year of study. It is only at first-year level that the huge number of students in lecture halls minimizes the personal contact with lecturers, thereby inhibiting the lecturers from shaping their minds in more ways than scientifically. However, ingenious and charismatic facilitators still find a way to overcome this obstacle, and the laboratory session with smaller groups (70 students per laboratory) is an ideal situation to exploit.

Student expectations of the various modules are ascertained on a regular basis at the end of each module (after a semester or a year). This information is viewed in earnest, and certainly taken into account in decisions on the approach to the new programmes. The first-year curriculum is still constantly being adapted to satisfy the six departments concerned, and meet the needs of (a)the involved lecturers with regards to background for their second-year curricula, (b)lectures needed to facilitate substantial knowledge on a discipline, and (c)the practical implications of facilitating a laboratory session in each discipline.

Specific needs of the students with regards to language of instruction, as well as a disadvantaged educational background, are also satisfied as discussed in detail previously (see **2.2.1**).

The programme content is still being adapted to the new 4:4:4 approach to the three years of undergraduate study. As students previously had only 3 subjects in their second-year, and 2 in their final year, these same subjects (e.g. microbiology, genetics and biochemistry) now have to be adapted to fit coherently with 3 other subjects into the final year of study. If the volume of work remains the same, but is simply fitted into less lecture hours, the students' workload simply increases unbearably.

The scientific quality of the BSc in Biological Sciences is completely relevant to international standards and expectations. One is impressed by the level of expertise of the staff involved, their international recognition and both the quantity and quality of their publications. Moreover, from second-year level the curriculum content is constantly being updated to include account of the most recent scientific developments. (The first-year curriculum is mostly adapted to ensure that students obtain the level of background knowledge as required for the second-year subjects.)

2.2.2.2 Programme coherence

The programme in Molecular and Cellular Biology is described as being highly coherent, based on the fact that 75% of the second and third-year programme is curriculated with an integrated focus on life on molecular and cellular level. The other 25% consists of a limited number of related compulsory and optional subjects. Methodological coherence is attained by a uniform approach to the research and study of molecular and cellular biology.

All this is clearly described in the US calender, which is updated on a yearly basis and available to every student. However, given the limited exposure to the scientific world that first-year students have had, it is dubious that they fully understand what awaits them. Even if the objectives of the programmes are clear, the students may not be sure what they want their own outcome to be. In this regard the interdisciplinary first-year curriculum, shared by all the programmes in Biological Sciences, Agriculture and Forestry is a move into the right direction. Now students can make a programme choice after a full year of exposure to all the different disciplines in the Biological Sciences. The second and third years then build on the foundation of the respective previous years, and both the theoretical and laboratory work become progressively more advanced. Eventually the BSc graduate has a sound foundation for further qualification as a molecular cell biologist. However, the foundation is broad and deep enough to allow direct entrance into the labour market.

With the new programmes still in an experimental phase the workload implied by the new curricula is not always clear. Investigation still has to be made by means of questionnaires to establish realistic requirements in this regard. As the new curricula are adapted from previous ones, and designed according to the number of lecture sessions available for each module, this aspect should be dealt with. It is only in the first-year curriculum that both lecturers and students are novices in the field of first-year biology. Never before at the US have biochemistry, genetics and microbiology been taught on a first-year level. Contact hours with each discipline are an absolute minimum: four hours in the case of cytology, genetics and zoology, and a maximum of eleven hours in the case of biochemistry.

However, the content of the lectures often cannot be minimized sufficiently without losing their significance and coherence. This implies that disciplines with the fewest contact hours often demand a significant amount of self-study from the students. For first-year students who are already struggling with their chemistry, physics and mathematics, with computer literacy as a compulsory extra, this can be overwhelming. Students' reaction on questionnaires from 2000 and 2001 included this remark (that the volume of work was overwhelming.) However, in the past pass rates were significantly better (above 85%) than the pass rates of chemistry, physics and mathematics. In these disciplines there was an alarming decline in the pass rates of first-year students in 1994 - 1998, leading to the conclusion that high school training in physics, chemistry and mathematics might have declined. Pass rates in 2000 and 2001 for Chemistry, Physics and Mathematics were unavailable, while pass rates in Biology have remained between 85%-90% since the start of the new programmes.

2.2.2.3 Teaching methods and student supervision.

In a field like Molecular and Cellular Biology, where theoretical and practical (laboratory) sessions are so closely related, it is imperative that learning activities will be adjusted to serve the objectives of the programme. Every module has a compulsory 3 hour practical session per week, and it is here that the newly acquired knowledge become practice, acquired skill, and marketable.

In the implementation of especially the new first-year curriculum in Biological Sciences it has become evident that also the teaching methods in theoretical sessions should be adapted to the objectives of the programme to ensure programme quality. Not many lecturers realised that class size has definite implications in the facilitation of a lecture, and in many cases newly acquired skills in computer technology were grappled with in the facilitation of lectures for close to 600 students. This is an aspect in the new programmes that definitely needs some attention. As the present students have grown up with a transformation in technology and computer aided application in every aspect of life, the use of new technology can be very fruitful in especially the Faculty of Science. Computer animations (Sanger, Brecheisen & Hynek 2001), digital camera equipment (Mills, Kelley & Jones 2001), CD-ROMs and multimedia (Simon 2001; Windelspecht

2001), Web-based modules (McLaughlin 2001) and Dynamic HTML (Gepner 2001) are just some of the new ways suggested for adapting the design and facilitation of Biology lectures with 21st century technology. This will definitely imply dedication from lecturers, as well as training of academic staff.

Assistance and support to students are addressed by the appointment of a coordinator for every year-group in every subject, e.g. Biology first-year, Microbiology second-year or Biochemistry third-year. This person should be available to guide students through their academic problems. However, as the coordinators are also lecturers with normal teaching schedules, they may not be available in times of need. In reality the administrative staff often has to fulfil this function, and they do not always have the necessary academic background to give sound advice. The lecturers can also be contacted by e-mail. This often results in a nightmare with staff being overwhelmed by electronic messages before deadlines and important events!

Guidance and support to students may indeed be an aspect that is often overlooked in determining the success rate of especially first-year students. In cases where such coordination was applied, mainly on temporary basis, it was extremely successful (own experience). To date the Science Faculty has been unwilling to appoint someone to the level of lecturer or senior lecturer mainly to coordinate the programmes, guide and support the students, and not be responsible for a research project as well. Removing someone from the academic staff to perform this task may have serious implications in his/her future career in higher education, resulting in a decline in motivation, which is immediately sensed by the students involved. One form of study service which may provide numerous opportunities for learning is that of student tutoring (Goodlad 1995). A scheme in which senior students are involved in supervision of especially first-year students, may be worth exploring.

2.2.2.4 Appropriateness of human, physical and financial resources.

The school for Biological Sciences is fortunate to have scientists with international recognition available as lecturers from first-year level. Every lecturer is assigned to a part of the programme relevant to his/her area of expertise. Even students in the foundational programme are mostly taught by faculty staff, together with experts in the curriculum development process of the ADP programmes. In this programme staff is often appointed on a temporary basis, with an annually renewable contract.

In the first-year curriculum the class of almost 600 students was split up into two groups according to the specific programme in Biological Sciences they were following . One of these groups was further split up into an English and Afrikaans group with lectures being facilitated simultaneously in the latter case. This implied that either three staff members from a single department were needed to lecture the first-year students, or two lecturers were needed, with one having to repeat every lecture on two different occasions. This calls for much dedication from lecturers, and an implication that lectures should be facilitated on a similar level by al three lecturers. Cooperation among colleagues becomes a necessity.

Staff is motivated for improvement in performance by a scheme allowing for regular peer evaluation. Even technical and maintenance personnel are judged by this scheme, according to which promotion is not granted without merit. In the case of academic staff the amount of research done, reflected in the number of publications in internationally recognised periodicals, is of great importance for promotion. Unfortunately this also implies that academic staff more involved in lecturing of students, do not get the same recognition as staff with a high priority on research, and less on lecturing. In some departments, i.e. microbiology, every academic staff member is given the same number of lectures and practicals on all graduate levels, disregarding the seniority of that staff member in the department. This leads to a feeling of team work and motivation especially with junior staff members – and students get a feeling of recognition and importance by being taught by e.g. the head of the department.

However, this is definitely not the case in all the departments involved in the School for Biological Sciences, and it does happen that academic staff are slowly manoeuvred to the edge of the staircase of success in higher education, by a gradual increase in his/her academic load. It also sometimes happens that a scientist is specialized in a more traditional field where his/her publications are not frequently quoted at present– e.g. taxonomy, or more descriptive morphology of botany and zoology. Such a person's publications may be regarded as being 'not as relevant' as e.g. biotechnology, cutting-edge genetics, biochemistry or microbiology. Sadly this will lead to scoring low merit points, with resultant stagnation in academic ranking. This definitely gives advantage to scientists in the new, emerging popular fields in biology – a situation regarded as being unjustified by the scientists involved.

The classrooms, laboratories and equipment are still being adjusted to meet the demands of the new programmes. Finances are always of great concern. With much of the research in the School for Biological Sciences being industry-related and –sponsored, financial resources have been adequate to supply at least the basic research facilities. In the development of the new programmes the first-year laboratories proved to be inadequate for certain so-called 'wet practicals'. The laboratories specifically equipped for biochemistry cannot accommodate 250 students simultaneously, as is demanded by the first-year curriculum. A lack of e.g. glassware put a restriction on the type of practical laboratory work that could be done by first-year students. Adjustments therefore still have to made to laboratories and equipment in order to plan the practical curriculum without being restricted by facilities.

Another concern is the need for a lecture hall big enough for the large class groups in the first-year curriculum. In most cases this group is split up into an English and Afrikaans lecture group, implying the need for two lecturers and two lecture halls to be used simultaneously. It does, however, happen that a specific part of the first-year curriculum can only be facilitated by a single lecturer, implying the need for a lecture hall seating 370 to 400 students. The few lecture halls with such capacity are overbooked. New facilities will have to be planned ingeniously to allow (e.g.) removable partitions between two adjacent smaller halls. Otherwise the application of the so-called 'electronic classroom' will be necessitated by this situation – causing its own restrictions on facilitation of a lecture.

A matter of concern is the tendency to address problems on administrative level, while instruction professionals (lecturers) are much better equipped to address the problem and find a solution that dissolves the need for more administrative staff.

There has been a steady increase in postgraduates at the US, which implies that more professionally qualified scientists should be available to help with undergraduate instruction. Of even greater concern is the statistics involving lecturers, non-professional administrative employees and student numbers. According to the Institutional Plan for 2000-2002 (Council of the University of Stellenbosch 2001) there has been a steady increase (3,5% –4 %) in student numbers from 1990 to 2002, with a peak of 6,5% during 1995-1999. However from 1998 – 2000 there has been a 4.5% decrease in the number of academic staff at the US, and a 5.24% increase in the administrative staff. When looking at the student: lecturer ratio for 2001, the statistics in the Institutional Plan (2001) roughly estimates less than 1000 academic staff members for more than 20000 students – i.e. a ratio of more than 20 students per lecturer, which compares poorly with situations abroad.

2.2.2.5 Programme effectiveness

As the programmes in Biological Sciences were only implemented in 2000, the first students following these programmes will only graduate at the end of 2002. The extent to which short-term objectives have been met in the attainment of the necessary skill levels targeted by the programme will therefore only be apparent from 2003. Long-term results will be affected even further into the future.

Potential BSc students are selected on the basis of their matriculation results, which should include mathematics, with one or both of biology and chemistry/physics. Students from previously disadvantaged educational backgrounds are recruited for the foundation programme as outlined previously. Students without the required grades for matric can also be allowed an entry examination after which entrance to the foundation or normal programmes can be attained.

Programmes are still being adapted continuously to avoid a repetition of failures once problem areas have been identified. Assessment of student learning is also in the process of change. Continuous assessment is applied by some departments (biochemistry, chemistry, mathematics). However, it involves an abundance of administrative and logistical problems in a module like Biology 124 which is facilitated by six different departments. The number of students to be evaluated throughout the first-year curriculum involves logistical problems in the writing of different tests by three groups of students having lectures at different times of the week, and practical sessions in three different time-slots. As no student is refused entrance to an exam before a minimum of two different assessment opportunities, and medical reasons for absence gives a student another opportunity for assessment, it can take up to four different tests, with all the paperwork and administration involved, to finalise entrance to an exam. Students may also decide to postpone their exam to December, then having only one opportunity to be evaluated. Evaluation of practical work is even more complicated, and this problem is still urgently being investigated.

2.2.2.6 The quality of programme management

Even before the implementation of the programmes was started in 2000, it became apparent that much coordination and close supervision would be a prerequisite for success.

Coordinators were appointed for every year-group in every department in the School for Biological Sciences. The establishment of the School for Biological Sciences addressed the issue of coordination among departments. However, even the physical movement to a single building did not remove all the barriers existing between different departments. One still gets the impression of departmental strongholds being built to exclude all intervention. Adaptation to the interdisciplinary design of the programmes may be an evolutionary process that takes time to develop.

In the first-year curriculum the planning of the fully interdisciplinary module Biology 124 necessitated the cooperation of the faculties of Science and Agriculture and Forestry. A committee to make decisions on module content, objectives and strategies was formed by representatives from all six departments involved. Coordination of the module is carried out by a single person, and recently another coordinator was appointed for the practical laboratory programme. However, these coordinators do not have authority over the lecturers and professional staff, but can mainly give advice and assistance with the smooth running of activities.

To my opinion there is a definite need for a professionally qualified person who can coordinate the entire first-year curriculum. Many of the problems encountered are applicable to all first-year modules involving the same students, and it is senseless to invent the wheel repeatedly when it has already been done by the department next door! The Council of the Faculty of Natural Sciences has the last word in all major decisions concerning changes in the programme. Problems concerning the content of modules are discussed and solved on departmental and interdepartmental level by committees especially assigned to a specific problem.

The programme's fundamental characteristics are not always clear to first-year students. There is a need for frequent repetition and clarification of the programme's fundamental characteristics, objectives, content and standards. This may be accomplished by a regularly updated website, e-mail correspondence with the concerned people, and office doors that are open to students.

2.3 PROGRAMME DEVELOPMENT AND STAFF DEVELOPMENT

When programmes of learning are transformed on the scale it has been done in the natural sciences at the University of Stellenbosch it is inevitable that staff will be challenged with scenarios and expectations unencountered before. Tizard, Minty and Newton (2001) describe the success of their transformation project as depending on the development of staff to meet the demands of new ways of working and teaching. However, the importance of staff development is not always realized, and proper needs-assessment for such programmes of development is not always carried out.

At the University of Stellenbosch the Human Resources Division, the Library, Information Technology, the Division for University Education (Uni-Ed), as well as the Research Development Office and the Financial and Student Record Offices, are involved in staff development programmes. The calendar with scheduled programmes for the year is available on the university's web site, and staff members can be nominated for some of the programmes, while others are open for enrolment until capacity is reached. The list of programmes indicates that a variety of problem areas are addressed, varying from psychological to financial, management, technological and educational. Orientation programmes for new academic as well as non-academic staff members are also available.

However, it is unknown whether the staff members really in need of such development programmes are actually the ones attending them. Personally I found that academic staff generally feel that their schedules of lecturing, mentoring, publishing and research activities do not allow them to attend any further "meetings", especially if they are not receiving any compensation for doing so. Time spent on attending staff development programmes would then rather be spent on writing research proposals, applying for grants, or performing various administrative tasks. Perhaps the art of delegation is one of the most difficult to be attained by academic staff, as pointed out by Ramsden (1998).

In essence a decision has to be made on the purpose of staff development programmes. What do the leaders want the lecturers to achieve? How will the staff development programmes enable them to achieve it? How will we know if the objectives of the programmes have been achieved? This closely resembles the ideas of Ramsden (1998) on performance management – which directly links with staff development.

The aim of staff development programmes should furthermore not focus on improving academic productivity only, but also to enhance academic satisfaction. The value of constructive feedback to attain the latter should never be underestimated. A competent academic leader will know how much focus should be placed on recognition to prevent a high staff turnover rate.

For staff in the School for Biological Sciences, and especially those involved in the demanding first-year curriculum, a proper needs-assessment inquiry should be performed to determine primarily which problem areas are requiring training and development. Teaching of large classes, the innovative application of technology, curricula planning (especially in the laboratory), and systematic introduction to the available services at the University to enhance teaching, are but a few aspects in need of development.

However, it should be emphasized that staff development is not a factor of attending a single programme or workshop. It should be carried out on an ongoing basis, with regular feedback on progress. It still remains a challenge to motivate the people in question to enrol for such programmes, and possible ways to compensate for attendance, which do not need to be financial, should be investigated.

The all-encompassing aim of staff development programmes should finally be in line with the mission and vision of both the university and the faculty. Moreover, the message that staff development programmes bring should be that the leaders of the university care – that academic staff members are treasured.

2.4 CONCLUSIONS

In his book *The quest for quality* Goodlad (1995) states that we are faced with a paradox: 'the rhetoric of the debate about quality seems to imply a unity of purpose and outcome that is at variance with common perception of the characteristic atomization of universities'. It is exactly in this paradox that the motivation for the current transformation in higher education lies. Moreover, a programme-based approach to learning fully addresses this unity of purpose and outcome, as underwritten in the mission of every faculty.

In the Faculty of Science the mission is 'to develop science through quality teaching and research, and to contribute to the well-being of society and the improvement of the quality of the environment'. After evaluation of the programmes in Biological Sciences it can be confirmed that a step has been taken in the right direction. It must be kept in mind that the design of the programmes should be regarded as evolutionary, and frequent evaluation, adaptation and ongoing commitment should lead to a fit-for-purpose result.

South Africa is a country that is geographically isolated from the western world. Academic staff should guard against an isolated approach to the development of the programmes. More international communication – and national conferencing on programme implementation – is a prerequisite for further successful implementation of programmes in the biological sciences.

The level of commitment by all people involved in the design of new programmes and curricula is conspicuous and encouraging. There was indeed an urgent need for renewal in science programmes, and the politically motivated transformation in this regard in South Africa came at the right time to be accomplished to the benefit of all.

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CHAPTER 3

The impact of software support on student learning.

3.1 INTRODUCTION

Society is being transformed by global competition and the power of technology. Change is the focus, with technology increasing the pace of transformation (Oblinger & Rush 1997).

According to Hooker (1997) changes in society can be either cyclical or structural – the structural changes being unidirectional and irreversible. In Higher Education the forces for structural change are provided by the information revolution and the management revolution, the latter being partly driven by our changing capacity to use information. In this new millennium knowledge will fuel prosperity, and those that can manage knowledge will enjoy a considerable advantage over those that cannot (Hooker 1997). The way that an economy develops its brainpower will become more important than ever before.

This leads inevitably to the emergence of a learning revolution. According to Oblinger and Rush (1997) the future stature of Higher Education depends upon whether our institutions are leaders of the learning revolution or bystanders. If we want to occupy 'the pivotal role in society' (Dolence & Norris 1995), we shall have to manage information competently and effectively. We shall also have to ask the right questions in rethinking education.

One question we must ask is how to improve learner productivity. Most articles deal with the need to increase faculty productivity. However, according to Johnstone (1992) doing less research and more teaching will not increase learning productivity. According to him 'learning productivity relates the input of faculty and staff not to enrolments or to courses taught or to credit or classroom hours assigned, but to learning, i.e. to the demonstrated mastery of a defined body of knowledge or skills'. He argues that significant and sustainable productivity increases must be achieved through greater attention to the learner.

One way to make learning more productive is for students to assimilate a body of knowledge in less time. Another way is to make it possible for students to get the courses they need when they need them. This is where technology comes in to allow us to focus on learning productivity without an impossible increase in faculty members and facility costs. Technology enables us to customize education, to provide options, and to allow students to study for as long or little as they need.

Teaching with technology promotes active learning by allowing students to restructure new knowledge to make meaning for themselves (Hellyer 1999). It makes education more learner-centred, and places the student at the centre of the learning process, thereby complying to the constructivist theory of learning.

However, not all technologies are created equal in terms of educational value. Facilitators should evaluate with discretion the technological methods and material to be implemented in a course. Creed (1997) identified several characteristics of good pedagogy that contribute to student learning. Electronic communication is one of the most beneficial technologies, giving students freedom to interact with course material, with lecturers and with each other. It increases accessibility to educationally sound information, enhances student interaction and participation in discussions, facilitates the submission of written assignments, and accommodates different learning styles. As electronic mail, the World Wide Web and computer conferencing can be used asynchronously, the advantages for utilisation of time and resources are tremendous (Chickering & Ehrmann 1997).

With all the positive effects of the application of technology, one problem that can occur with the incorporation of technology into science classes is the emergence of a dual learning curve. The additional requirements involved in learning to manipulate multimedia presentations and programs may imply extra demands on instructor time and resources, thereby reducing teaching effectiveness. However, with the increase in the use of information technology at a younger age, basic computer and information technology skills may soon be considered as generic.

Students are mostly very receptive to the use of technology, and technology is used more and more in the classroom (Nantz & Lundgren 1998). In the Biology classroom as well as the laboratory, technology has found many useful applications. Mills, Kelley and Jones (2001) describe the usefulness of a digital camera, mounted onto a microscope, and attached to a laptop computer, to document student observations in a Microbiology laboratory class. A variety of video-based technologies are also available over the Internet (Francis 2000). Computer-based animations, as well as interactive video, provide powerful resources. As the interpretation of visual information is a major means of acquiring understanding, dynamic processes are best understood if illustrated by GIF (Graphics Interchange Format) animations, which can easily be incorporated into a Web page (Slish 2000). Sanger, Brecheisen and Hynek (2001) report on the fruitful application of computer animations to facilitate students' understanding of diffusion and osmosis, while Gepner (2001) applies dynamic HTML to make 'pages that move' in the Biology laboratory. Realising that her Biology students need to be doing things and thinking about the things they are doing, McLaughlin (2001) transformed her lecture into an active learning forum with the application of web-based interactive learning modules. According to Gardner (1983, 1993) students prefer visual learning because of their culture (growing up with the Internet, media imaging, television), and because Biology is not static, but dynamic and full of movement and life. Things have become easier since CD-ROMs were developed, and Simon (2001) describes a series of classes in which technology usage was taken to its ultimate degree: as a replacement for, rather than a supplement to, a traditional textbook.

3.2 THIS CASE STUDY

At the University of Stellenbosch the School for Biological Sciences developed an interdisciplinary approach to first-year biology teaching since its establishment in 1998. The new programmes in Biological Sciences implemented in 2000 contain first-year curricula that introduce students to the disciplines of genetics, zoology, botany, microbiology, biochemistry and statistics. This provides first-year students with more information than in the past to choose between the various disciplines for the second and third years of studying towards the BSc degree. Programmes are more market-orientated, and modules are combined to equip students for entrance into a specific career.

All students in the Biological Sciences programmes of the BSc degree, all BSc Agric, BSc Forestry, BSc Food Science and BSc Consumer Science, as well as students in Human Movement Science and in some programmes in the Physical Sciences follow the same module Biology 124 during their first semester of first-year studies. This leads to classes of up to 600 students, with lectures given both in English and Afrikaans, by lecturers from six different departments (Botany, Zoology, Genetics, Biochemistry, Microbiology and Nature Conservation). Because only four to eleven lectures are facilitated in the various disciplines in the module, and the content often cannot be diminished to "fit into" such a short contact-time without losing its coherence and significance, much of the information is given as core notes, and self-study by the students become more and more important. It is therefore not surprising that the first-year students find the mass of information overwhelming and confusing, and lecturers are becoming concerned about the pass rates for Biology 124, as well as the average percentage scored for some parts of the module.

New ways are therefore investigated to make information more comprehensible and coherent for the first-year biology students. As the Biology Handbook (Raven & Johnson 1999) for the first time in 2001 came with a CD-ROM as supplement to the student edition, it could provide the students with a valuable and appropriate means to facilitate self-study. The CD-ROM gives an overview of the material, and contains interesting animations, video-clips, quizzes and summaries. Using the CD-ROM would enable the students to construct their own knowledge in their own time, thereby promoting active learning and giving them more control over their own learning process.

The aim of this research project was to ascertain whether the students actually used the CD-ROM, and whether they found it applicable to their specific problems with the module Biology 124. The frequency at which they used it, as well as reasons for not using it were also determined. The students' need for enhanced computer-facilitation throughout the course, as well as the general use of the available IT facilities by the biology students, were investigated.

As all BSc students follow a compulsory course in computer skills they should be able to use the CD-ROM. However, their previous familiarity with IT facilities may vary, making the use of electronic media more difficult for some students. As in the first-year group of Windelspecht (2001) this may lead to a dual learning curve, with some students spending more time in mastering the electronic skills, than benefitting from the information received via the computer.

Due to the existence of the following variables between the Biology 124 course in 2000 and 2001 it will not be attempted to find a correlation between the pass rates of the different year groups and the use of the CD-ROM:
(1) the composition of the module as a whole was changed from 2000 to 2001, with more or less contact hours given to the different disciplines involved in the module (2) the material presented by the different disciplines varied between 2000 and 2001 (3) a practical laboratory course was fascilitated synchronously with the theoretical course in 2001 to enhance understanding of the theoretical lectures. This was not done in 2000, and may provide an additional influence on the pass rates. However, in 2001 all Biology 124 students followed the same theoretical and practical biology course.

3.3 METHODS

3.3.1 Research group

The research group consisted of the 560 first-year students following the module Biology 124 in 2001. As previously stated they are following different programmes of the BSc degree, leading towards various degrees (BSc Agric, BSc Forestry, BSc Consumer Science, , BSc Biological Sciences, BSc Human Movement Science and BSc Physical Sciences). Due to variation in the requirements for the various degrees they did not all have both Biology and Science (Physics and Chemistry) as matric subjects.

3.3.2 Instrumentation / Questionnaire

All information was received by questionnaire, which was completed by all Biology 124 students after the first test series, but before the end of the course. Because many students only start making use of the available resources once they start studying for the test series, it was considered advisable to wait with the questionnaire until after the test. However, as the Biology 124 group split up after the first semester, and not all students continue with Biology for the rest of the year, questionnaires could not be completed after the first semester examinations. Information on pass rates and average marks were received from the coordinators and administrative staff. Pass rates for the whole first-year biology group, as well as average marks scored for the examination paper and different sections of the module were compared with those of 2000.

The questionnaire (see Addendum 1: Section A) was compiled to provide information on the following issues:

(1) Test mark (first semester for module Biology 124).
(2) Gender (male /female).
(3) BSc programme followed (four possible answers).
(4) Biology and/or Science as matric subjects.
(5) Use of the CD-ROM supplied with the handbook) (Yes/No).
(6) Frequency of use of the CD-ROM (Four possible answers).
(7) Evaluation of the CD-ROM (Five possible answers provided).

(8) Reasons for not using the CD-ROM (5 possible answers provided).

(9) Use of the Internet Yes/No)

(10) Need for e-mail communication with the lecturer (Yes/No).

(11) Use of own computer on campus (Yes/No).

(12) Opinion of IT facilities on campus

(13) Need for more intensive use of the University's network (5 possible answers).

3.3.3 Data analysis

An Excel spreadsheet was created with 33 columns presenting the possible responses, and a row for each respondent's answers. In this way a 33 X 406 matrix was created. A statistical analysis was performed of the entire matrix to determine if any correlation existed between any of the variables (see Addendum 2). The graphical functions included in the Excel software package were used to present the data visually.

3.4 DISCUSSION OF RESULTS

Of the 560 students completing the Biology 124 course, 406 returned a completed questionnaire to be used in this analysis, implying a return rate of 71,2%.

Statistics on the students' marks in 2000 and 2001 for the module Biology 124 as a whole, as well as the different sections of which the module is compiled, are summarized in Figure 1.

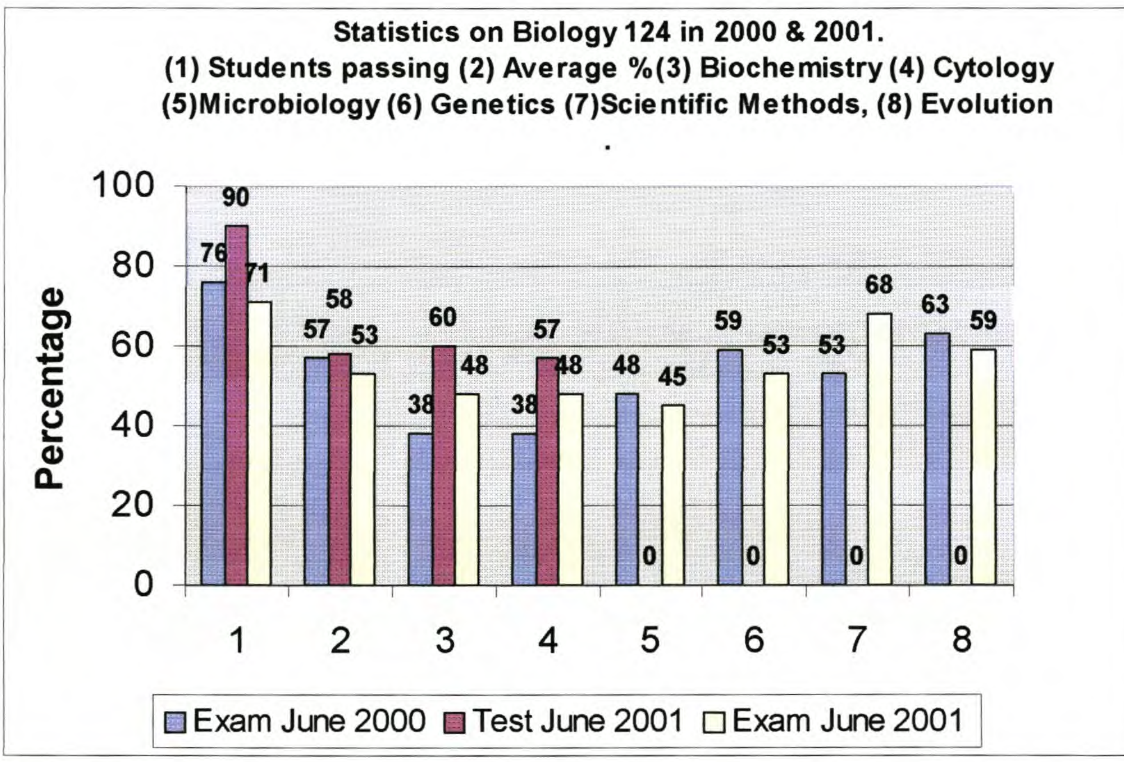

Figure 1 : Statistics on Biology 124 pass rates and percentages. A "0" indicates that no test was written for that part of the module (see Test June 2001).

An interesting phenomenon was revealed by the students' evaluation of the module. In the two sections which the students rated as being most informative, Cytology and Microbiology, and in which they indicated the practical sessions to be most meaningful, they had the lowest scores in the examinations. Both in 2000 and 2001 Cytology was indicated as the easiest part of the module, but the average percentage was still the lowest (38% in 2000) and second lowest (48% in 2001). For Microbiology the situation was just reversed. These sections of the module specifically consist of work that has to be understood and memorised, without mathematical or statistical calculations to be done. The CD-ROM should enable the students to get a better visual perception of the content and dynamics of both sections Cytology and Microbiology.

An investigation into the composition of the biology class (gender and course followed) resulted in the following statistics (Figures 2, 3 & 4).

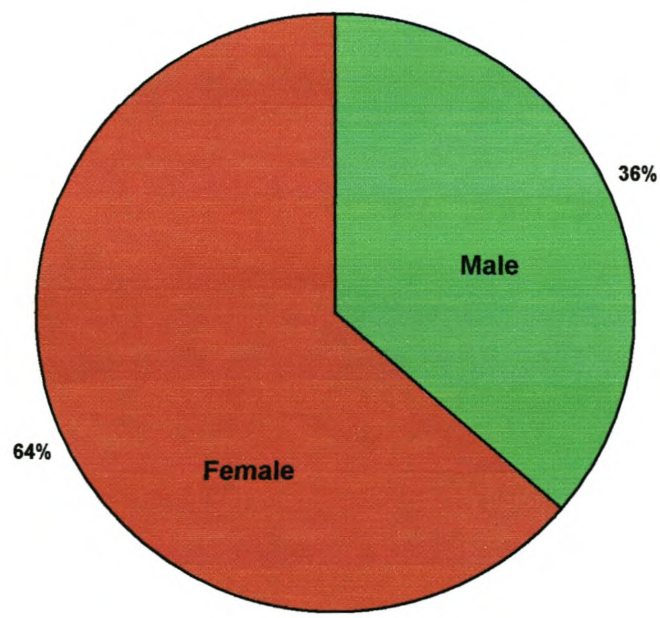

Figure 2 : Gender of students following Biology 124

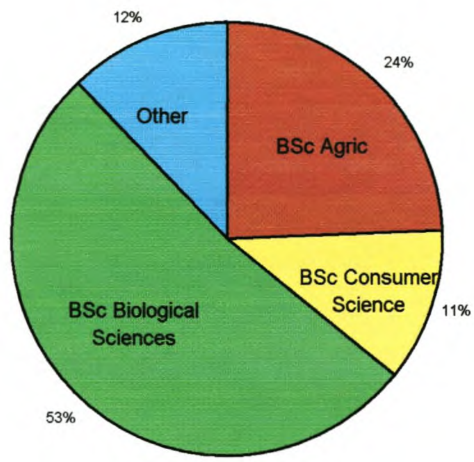

Figure 3: BSc programmes followed by Biology 124 students

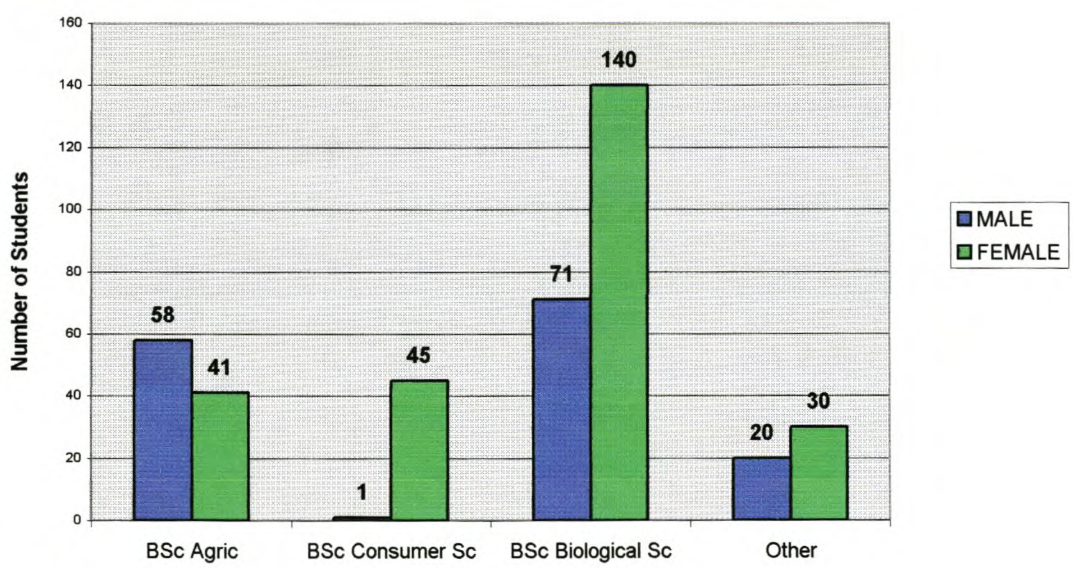

Figure 4: Gender of students in different BSc programmes

The class is predominantly female (64%), though this is not reflected in the individual programmes followed by the students. Students following BSc Agric are predominantly male (59%), while 98% of the BSc Consumer Science group is female.

The first question relating to the issue being investigated was to ascertain which students used the CD-ROM supplied with the textbook, and which not. Results (Figure 5) revealed that only 102 respondents (25%) of the Biology 124 students used the CD-ROM for studying. The rest (304) were requested to give the reason for not using the CD-ROM. In Figure 6 can be seen that 43% of the non-users did not have a copy of the CD-ROM. The reason may be that :

(1) many students bought second-hand books from the students of 2000, when the CD-ROM was not yet supplied with the students' edition of the handbook
(2) in the book shop on campus the old stock of 2000 (without the CD-ROM) was on the shelf with the new stock (which included the CD-ROM). As the old stock was sold at a lower price, many students bought it without realizing that a CD-ROM was included in the new impression of the book.

The second most influential reason for not using the CD-ROM was that the students (29%) did not have access to a computer with a CD-drive. At the computer centres of the University of Stellenbosch where the first-year BSc students have access, few computers are equipped with a CD drive. This implies that only students with their own computers and a copy of the CD-ROM could actually have easy access to the information on CD. Another problem which some students mentioned, was that the computer centres recently upgraded to Windows 2000, while the CD-ROM can only be run on Windows 1998. The operating system thus prevented students from using their included CD-ROMs. A few students (12%) also indicated that they did not have the time to use the CD-ROM, probably because they have to stand in long queues before getting access to a computer, and then they have enough other assignments to be completed on computer. Only 9% of those that did not use the CD-ROM actually found it unnecessary to study from, and another 7% did not know how to use the CD-ROM.

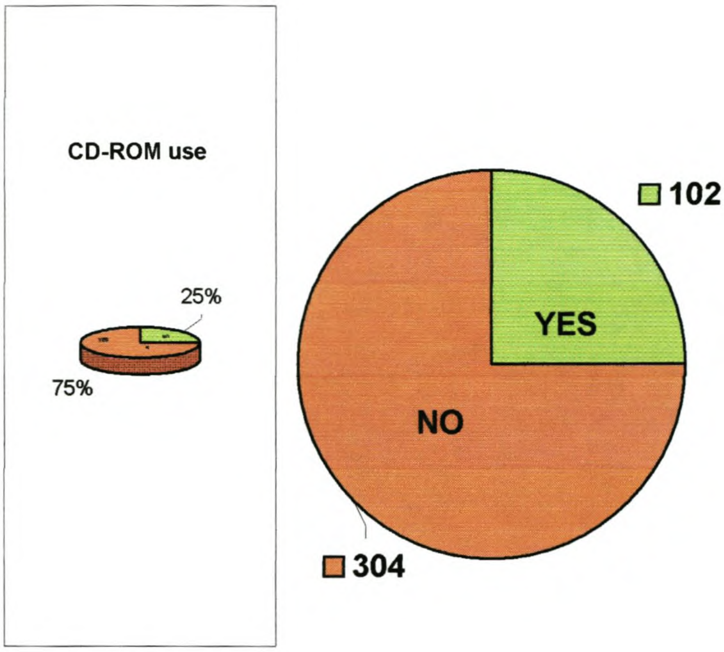

Figure 5: Number of Biology 124 students using the CD-ROM

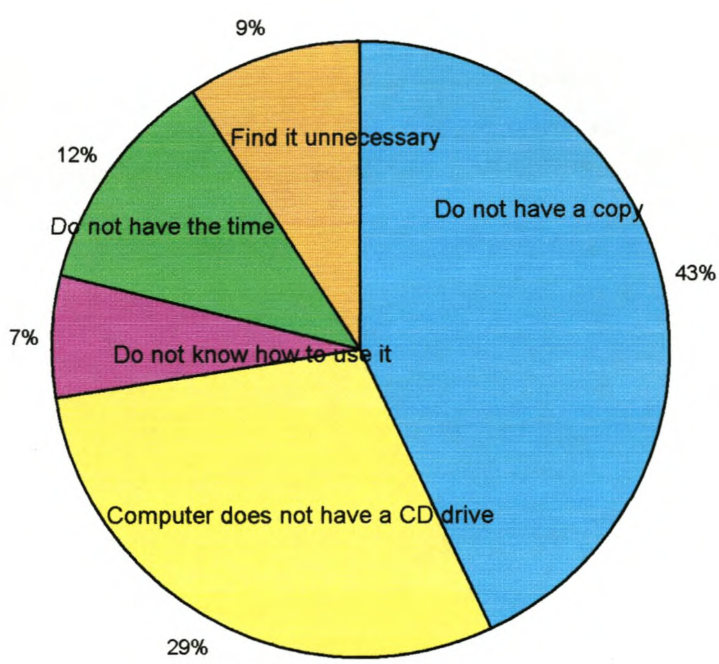

Figure 6: Reasons for not using the CD-ROM

Further focus on the students who did make use of the CD-ROM to facilitate self-study revealed that the frequency at which they made use of the software, varied as follows (Figure 7): 57% used the software just before tests and examinations, 31% used it once per week to once per month, while 8% used it now and then as the opportunity arose, and 4% used it once or more per week.

The 102 students who did use the CD-ROM were requested to give their opinion on the software (Figure 8). Most found it interesting (98%), and providing a good summary of the work (94%), while 69% thought it related well to the class notes. Only 11% found that it just increased the volume of work, while 7% found it confusing. The students who did use the software therefore felt positive about it, and used it mostly to facilitate self-study before tests and examinations.

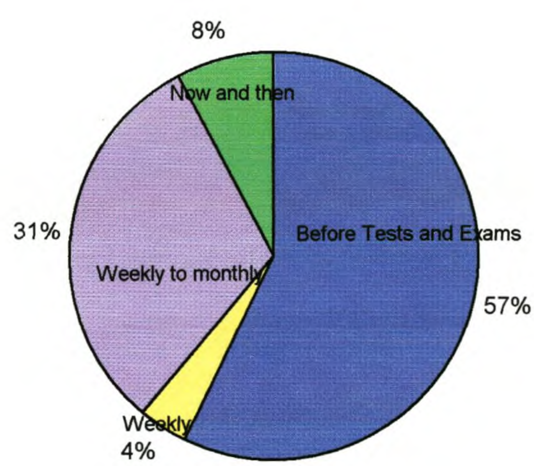

Figure 7: Frequency of using the CD-ROM

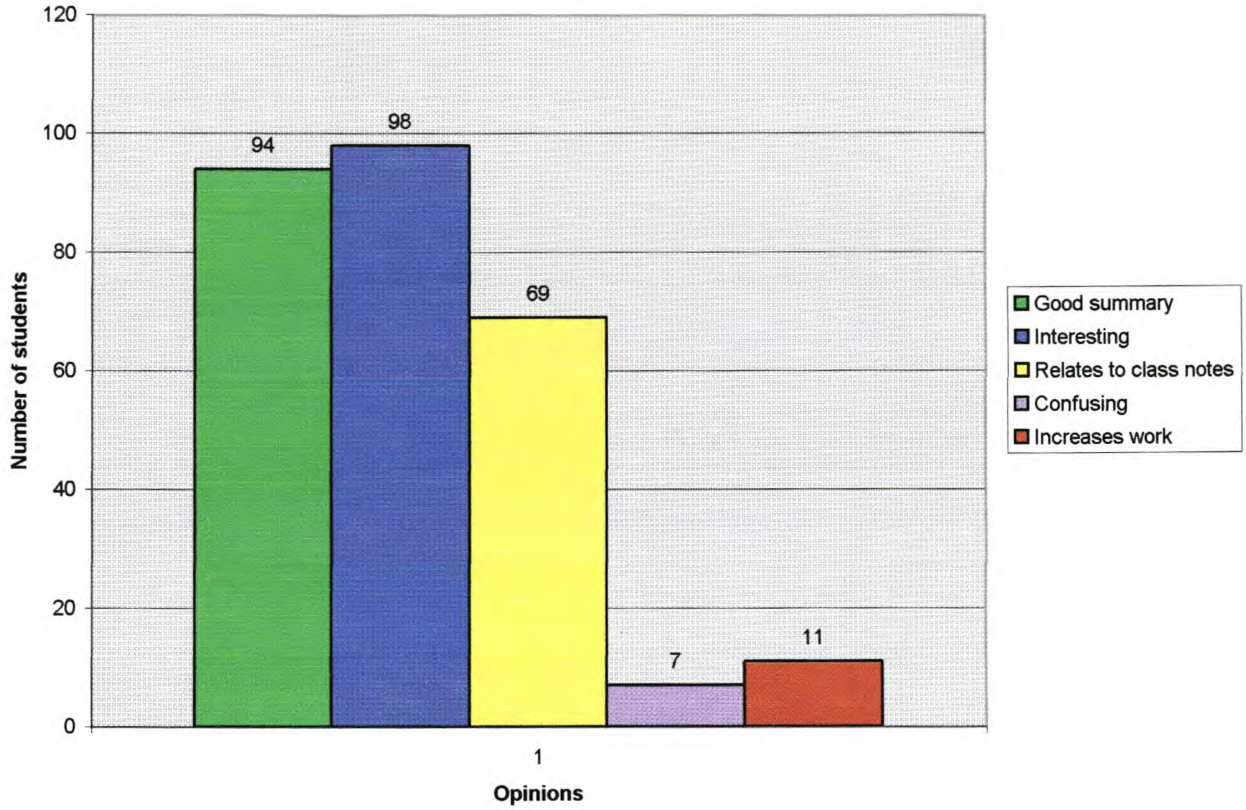

Figure 8: Students' opinion of the CD-ROM

When looking at the scientific background of the 406 respondents, it is interesting to see that 331 (81%) of the students had both Biology and Science as matric subjects, with only 34 (8%) having Biology only, and 43 (11%) with Science only (Figure 9). It can be assumed that these 77 students who lacked either Biology or Science as matric subjects were in greater need of a study aid to improve their background knowledge. However, analysis of their response to the questionnaire revealed that in both cases only 33% of them used the CD-ROM. Most of them therefore relied mostly on their class notes or the textbook to study Biology – probably just managing to keep up with the mass of information presented in class, and not having the time to pursue new ways of assimilating the knowledge!

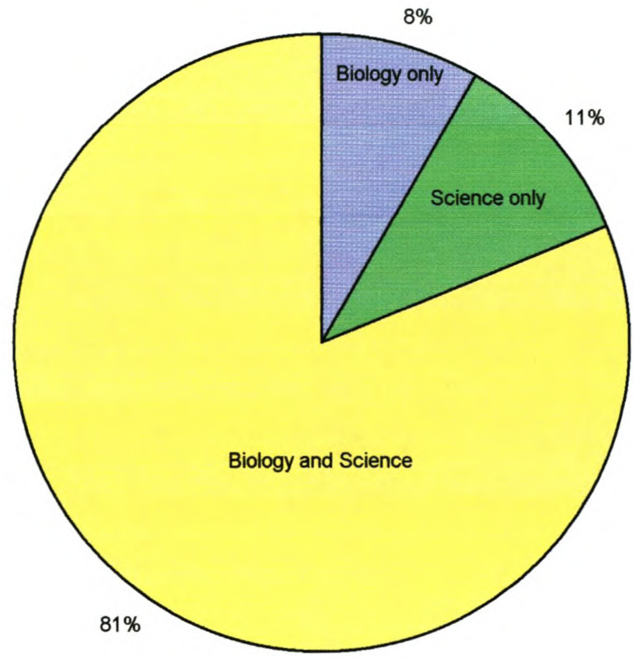

Figure 9: Students with Biology and/or Science as matric subjects

When considering the small percentage of students who used the CD-ROM (Figure 5), mainly due to a lack of hardware and software (Figure 6), attention was given to the students' response to questions concerning general IT use. Figure 10 illustrates that only 25% of the students use the Internet for their studies, while 39% have their own computer, and 67% would like to have e-mail contact with the lecturer.

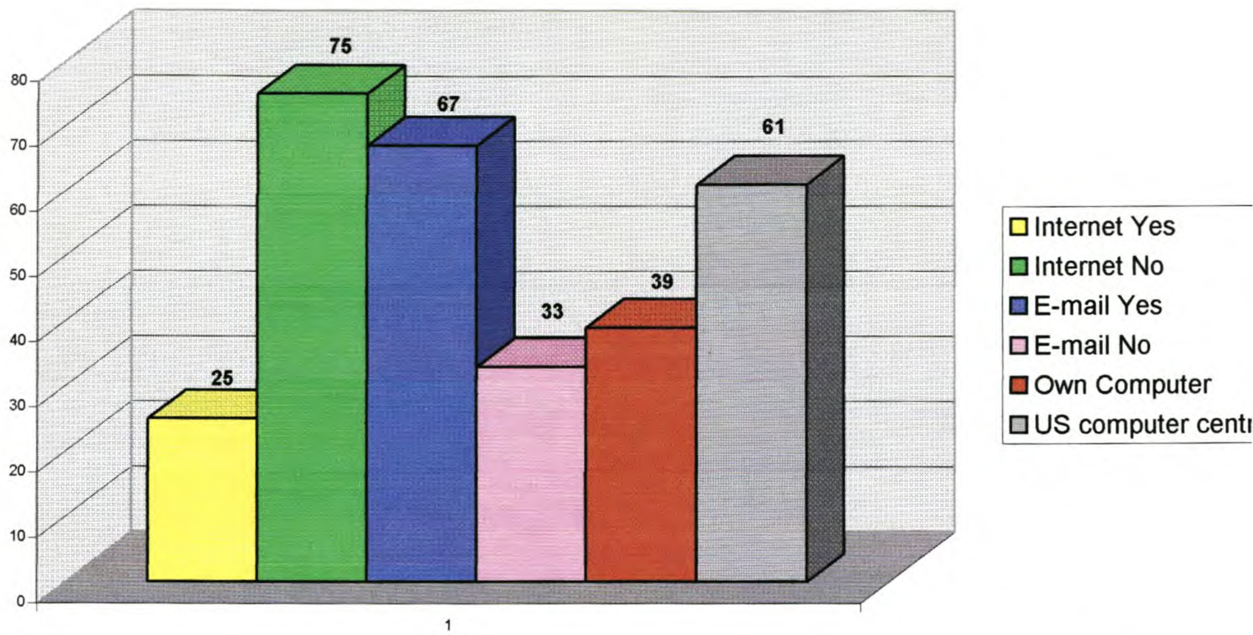

Figure 10: Relative percentage of students using the internet, needing e-mail contact with the lecturer, and using their own computer.

When correlating the use of information technology with the use of the CD-ROM the following Table can be compiled (Figure 11):

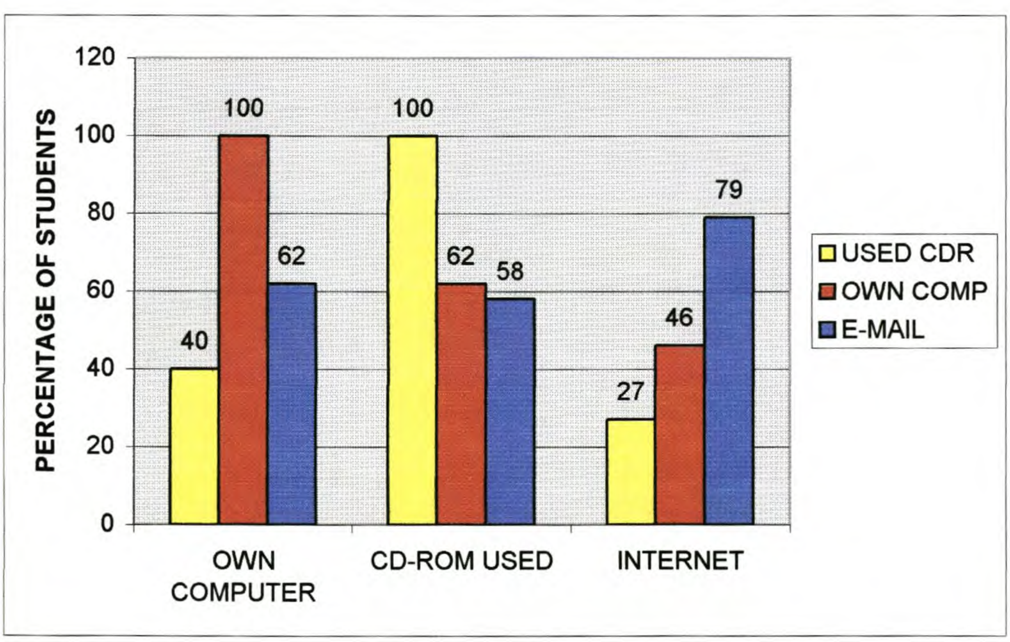

Figure 11: Relative statistics on CD-ROM use, computer access, internet use and e-mail requirement. (CDR=CD-ROM, COMP=Computer).

Of the students using the CD-ROM 62% also used their own computer for doing so. In this way the university 's shortcomings with regards to the lack of CD drives, enough computers and operating system could be overcome. 62% of the students using their own computer also expressed a need for e-mail contact with the lecturer. These students will naturally be more familiar with using a computer, and such communication with a lecturer will be much easier than making an appointment with him/her in an office. Undergraduate students, especially first-year students, often feel reluctant to confront the lecturer with his/her questions. Electronic communication, being asynchronous and furthermore not face to face with the lecturer, provides a way to overcome this obstacle. Only 46% of the students with their own computer used the internet to get information concerning their studies. This may be caused by the fact that the Internet, although available at a much cheaper rate for university students, still has financial implications for the students. On the other hand, the university's network operates free of charge for the students, and can be used freely for e.g. local e-mail. Of the students using the CD-ROM 58% also need e-mail contact with the lecturer, while only 27% also used the internet. Of the 100 respondents using the internet, 79% were also interested in e-mail contact with the lecturers.

Another graph (Figure 12) summarizes the use of IT facilities by students in different programmes of the Biological Sciences. In all cases 25% of the students used the CD-ROM, irrespective of the programme they were following. The BSc Agric students (44%) and the students grouped as "Other" (Earth Sciences, Polymer Sciences, Bio-organic Chemistry and Chemistry for the Industry) (48%) had the highest percentage of personal computers. 34% of BSc Biological Sciences students, and 35% of Consumer Sciences students had their own computers. It is interesting to see that possession of their own computers did not necessarily imply greater use of the Internet as source of information from which to study. Only 16% of the group with the highest incidence of personal computers used the internet, while 25% of the group with the lowest incidence made use of information on the internet. This is probably a result of the cost involved in Internet use. The BSc Agric students have the highest percentage of Internet users (32%). The need for e-mail contact with lecturers varies from 62-69% among the different groups of students. It is not surprising that this figure is relatively high, as students have free access to the university's network, and can send e-mail unhindered and free of charge.

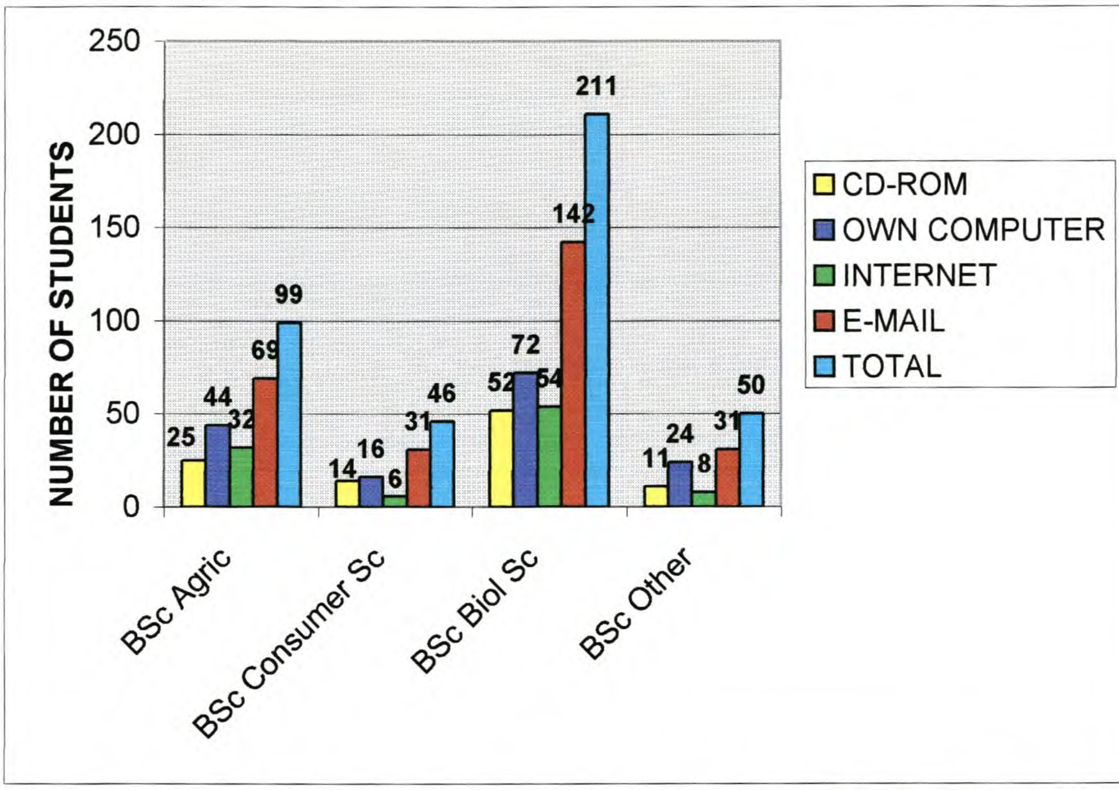

Figure 12: Use of IT facilities by students from different BSc programmes.

When considering the students' test marks in the light of the availability and use of the CD-ROM, comparison of the different percentiles with the use of the CD-ROM (Yes / No) immediately reveals that no influence on the test marks can be attributed to the use of the CD-ROM. In the top 25 percentile only 17 out of a possible 81 (i.e. 20%) students used the CD-ROM for studying purposes. It is therefore not surprising that the test mark revealed no correlation with the use of the CD-ROM.

A statistical analysis was performed on the entire matrix, in order to ascertain whether any significant correlation existed between any of the variables responded to on the questionnaire. All major aspects of the study were examined, but no significant correlations revealing new insight could be found (see Addendum 2)

In another part of the Biology 124 module – i.e. the section on Statistical Methods – no lecture notes were available, and the core ideas were made available as CD-ROM copies to be borrowed at the university library. At the same time the identical information was loaded onto the university's network. Less than 20 students made use of the CD-ROM copies at the library, but within the first week 450 students downloaded the information from the network (Ward 2001). The university's own network therefore provided a much more accessible means of obtaining electronic information than the CD-ROM.

An analysis of the students' response to the questions concerning the use of the University's website, to which they all have free access, resulted in the following interesting information (Figure 13):

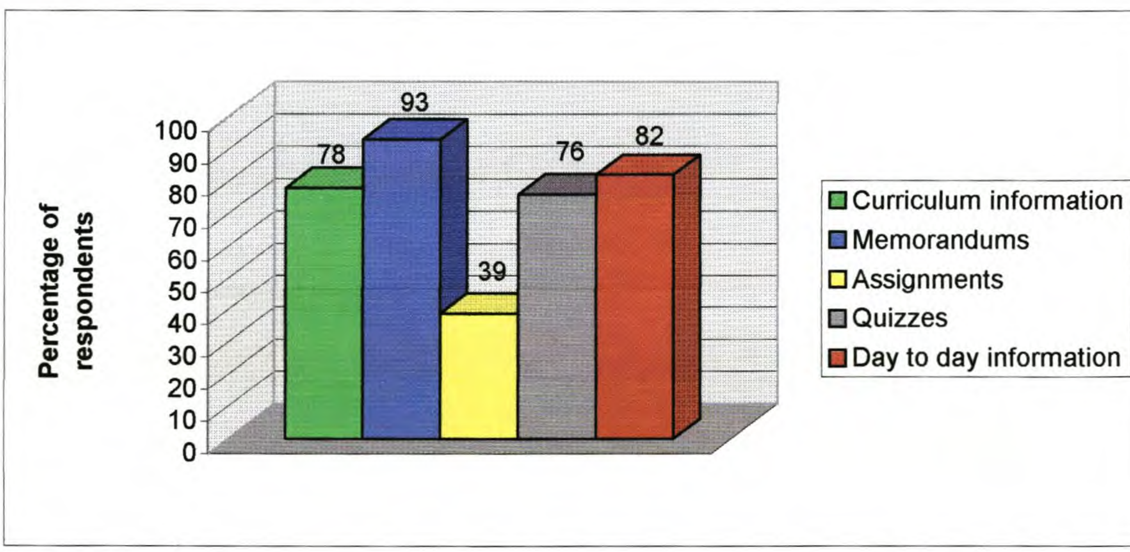

Figure 13 : Need for information to be provided on the university's website (Percentage of respondents indicated).

The need for information to be provided on the university's network was almost unanimous. Only one student indicated that she did not have any more time to search for additional information. It is interesting, but not surprising, to see that the need is mostly for various types of information (curriculum information and day to day information on results, venues, important dates, etc), as well as for the facilitation of quality learning (quizzes and memorandums). Only 39% of the students wanted the network to be used for assignments, probably fearing an overload of work.

At the University of Stellenbosch all students have access to a computer at a computer centre. On the questionnaire the respondents' free opinion of the IT facilities at the University of Stellenbosch included 149 (i.e. 37%) complaints about the shortage of computers. At the moment the ratio of students to computers is 10:1. The IT section of the University is in the process of upgrading this to 5:1 (Dreijer, H. 2001). This will improve the availability of computers to students, shortening the waiting time at computer centres, and allowing students more time to complete assignments digitally, or presenting it on the network.

3.5 CONCLUSIONS

The results of this study confirms that the existence and availability of information technology does not necessarily imply its use, application or advantage to be gained. Apart from the high number of students not in possession of the CD-ROM, a great number of those who did possess it could not use it due to the fact that they did not have access to computers with CD drives. The advantage that students with their own computers had over those who did not, is therefore conspicuous.

Internationally it is becoming a major concern that opportunities for the access and use of electronic media are limited by the availability of such forms of information and communication to people of limited income. This leads inevitibly to an advantage to people with the financial resources to provide access – and a disadvantage to people in underserved and rural areas. This phenomenon has become known as the "digital divide", and according to Ivy Matsepe-Casaburri, SA Minister of Communications (2001), one of the biggest challenges of the twenty-first century might be "bridging the digital divide". SA President Thabo Mbeki recently launched an International Presidential Task Force on Information Society and Development, constituted by prominent directors and executive officers of Hewlett-Packard, Oracle, Siemens and Nokia. Recently the Ministry and Department of Communications launched their publication Bridging the Digital Divide, which they hope will contribute effectively to closing the information gap.

In this study some effects of this phenomenon were detected, albeit on a very small scale. The development of pedagogically sound digital media to enhance learning without causing a dual learning curve has only begun, and promising applications on the internet, local networks, interactive video and animation are being developed. Apart from the digital divide, one of the main concerns remains the development of skills to utilise these digital novelties to their fullest. However, the student generation of today has had much more exposure to electronic information than the previous one – and within five to ten years the generation of young academics will be much more familiar with digital equipment and its application. Many lecturers are painstakingly working at incorporating more digital media into their lectures, and students are receptive to such a transformation – although their criticism may be acute. The use of the university's internal network can still be developed and applied to many problem situations with large classes, changed curricula, intensive practical sessions, etc. This study has shown that the network is the most accessible of electronic information pathways available to all students 24 hours a day. We as facilitators of learning have to be learner centred and develop our own skills to utilise this learning aid. We can thus pave the way for the students to become self-regulated learners.

Computer literacy has already become a prerequisite to benefit fully from higher education. From a certain level computer skills have become generic – and this is expanding globally. Students can no longer do assignments, search for library material, or even get access to laboratories without acquiring some computer skills.

In the words of Hooker (1997): 'If we are serious about learning, the learner should be our focus.' Technology can and will provide the means by which learning can be facilitated in ways which are presently unimaginable. It is our responsibility not to become spectators of this explosive force, but to equip ourselves and our students to ride the wave, take control of our own learning, and move to the centre of our own learning process.

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CHAPTER 4

Teaching statistics to first-year biology students: a new approach

4.1 INTRODUCTION

Statistics is a part of everyday life. In science the accumulation, manipulation and comprehension of data is becoming increasingly indispensable. However, students often find it a daunting prospect to use statistical analyses in the interpretation of their data. Moreover, in the past students in the Biological Sciences have mostly been introduced to statistics only in their post-graduate years. Nolan and Speed (1999) describe their own and other attempts at designing new models for teaching statistics. Cobb and Moore (1997), Foster and Smith (1969), Hogg (1985), Kempthorne (1980) and others have recently called for the design of better one-semester statistical courses that integrate data analysis into the curriculum. Many consider training in statistical thinking important e.g. Daisley (1979), Joiner (1989), Schuyten (1991) and others. The most important goal is generally to encourage and develop statistical thinking, and to give students experience with how statistics can be used to answer scientific questions.

Before the development of new programmes of learning at the University of Stellenbosch, statistics had never been taught to first-year students in the Biological Sciences. The new programmes that were implemented in 2000 include a multidisciplinary module Biology 124, introducing students in the Biological Sciences to the disciplines of genetics, zoology, botany, microbiology, biochemistry and statistics.

4.2 BACKGROUND

In the first year of implementation of the new programmes of learning (in 2000) the students scored poorly in the statistics part of the Biology module, with a mean of 53% and a mode of 40-49% for the June examination. That made it the second lowest score of the six parts of the module. In the December examination the mean score of 35% was the lowest compared to the other parts of the module. Moreover, student feedback after the course was very negative, rating statistics as the part which they (a) enjoyed least, (b) found least interesting, (c) experienced as very difficult, and (d) regarded should be down-scaled (see Figure 2). It was described by some as being “dry and uninteresting”.

Their poor performance in the examination and low rating of the statistics section of the module influenced the committee involved in curricula planning to design a new modus operandi. Complicating factors are that the section of the committee representing the Department of Agriculture and Forestry is in favour of down-scaling the module, as their curricula include comprehensive statistical training from the second-year level. On the other hand the representatives from the Department of Natural Sciences regard this novel inclusion of statistics in the first-year biology course as indispensable, as many of the students in the biological and life sciences have little exposure to statistics and no training in mathematics later in their undergraduate years.

A probable solution was provided by an introductory statistics series designed by Prof. Ward of the Department of Nature Conservation, which he calls *How do we do Biology?*. With this series of eight lectures (one hour each) and two practical sessions (three hours each) he planned to introduce first-year students to interesting case studies in which statistics have provided the invaluable tool, i.e. where the scientific method has proved the case. The lectures have catching titles, which would appeal to the students, resulting in a captive audience. According to Ward (2001) the students should recognise (1) that biology is exciting, (2) that progress in science occurs in various ways, and (3) that scientific results do not need to be clear-cut in order to contribute to the notion of progress in science.

4.3 LEARNER GROUP

The group consisted of 570 first-year biology students following different programmes in Biological Sciences, Agriculture, Forestry, Life Sciences, Consumer Sciences and Human Movement Science. Students all had mathematics as a matric subject, but not all had both biology and science up to the same level. Due to the "language friendly" approach to first-year teaching in the School of Biological Sciences, all lectures are facilitated both in Afrikaans and English, in two lectures halls, by two lecturers. Sometimes the lectures are facilitated simultaneously, and on other days in different time slots. This implies that one group has already had its three weekly lecture sessions, when the other group still had two to attend. Practical sessions of 3 to 4 hours each were facilitated on two afternoons and one morning per week.

4.4 GENERAL LOGISTICS

After scrutinizing inquiry and reflection upon the content of the lectures, the objectives of the course and the expectations of the students, it was decided that Prof. Ward would be the only lecturer facilitating the theoretical lectures, while the practical sessions would be facilitated by both of us. As coordinator of the module I would handle the logistics concerning the facilitation of lectures to almost 600 students, while Prof. Ward's postgraduate students in Nature Conservation would act as student assistants in the practical sessions. As Prof. Ward is English-speaking, Afrikaans-speaking students would have to compromise on their language of instruction, but this would be compensated for by the implementation of technology. All lectures would be facilitated as "PowerPoint" presentations, using two data projectors on two screens, one in English and one in Afrikaans. Although the language of instruction would be English, students were free to converse with Prof. Ward in Afrikaans. Tests and examinations would be in both languages, and assignments and reports could be completed in the language of choice.

The biggest obstacle would be finding a lecture hall big enough for such a large group of students. As the new interdisciplinary programmes resulted in much larger classes than before, the university's few large lecture halls with seats for more than 300 students, were fully booked. This is something that should be kept in mind in future programme and curriculum planning. The final solution to this problem was the use of the Endler Hall, a concert hall in the Conservatoire of Music, with 530 seats. In many ways this was not the optimal choice : no projection screens are available, no power sockets are in the hall, no podium for the lecturer or writing-desks for the students, and no microphone system for the speaker. As this concert hall was designed with excellent acoustics for concert performances, the lack of a microphone system proved to be of no consequence, and power extension chords were led into the hall. Large projection screens were rented and put up before every lecture. The students were even sometimes surprised by organ music from students still having their organ lesson while they were taking their seats! The final obstacle was provided by the disappearance of one data projector just before the start of the first lecture, resulting in its replacement by an overhead projector, and the Afrikaans lectures being put on transparencies.

According to Gillespie (1996) large classes should be analysed, and practical strategies identified to overcome problem areas in lecture facilitation. The availability of professional support staff, as well as teaching and technical assistance allowed us to create exemplary and effective learning environments, especially in the laboratory. The use of new instructional technologies, aimed at enhancing information presentation, proved to be invaluable.

4.5 OBJECTIVES / LEARNING OUTCOMES

As previously mentioned the main objective of the series of lectures was not to teach students statistical formulae, mathematical functions or theoretical statistics. It was rather to introduce them to the scientific and statistical way of thinking, and show them how statistics can be used to answer scientific questions. They should rather be motivated and encouraged to explore the scientific way of reasoning, and recognise it when they encounter it in everyday life. In this way student learning and success would be produced in a cooperative and supportive learning environment. This is in accordance with the learning paradigm as suggested by Barr and Tagg (1995). The lecture content would provide a holistic approach to statistical thinking, and students would be encouraged to construct their own knowledge in a cooperative and supportive environment, thereby allowing them to become active learners.

As lasting learning is promoted when students are actively involved in thinking about what is being heard, seen or done (Lord 1998, 2001), the practical sessions would provide an excellent milieu in which this theory could be applied. An old Lakota Indian saying formulates it descriptively: 'Tell me and I'll listen, show me and I'll understand, involve me and I'll learn' (Millis & Cottell 1998). In the practical sessions the students would therefore be introduced to the process of data collection and analysis, using very basic data that could easily be obtained from each other in the lab, and requiring the minimum of equipment. They would work in groups, discuss their views, make suggestions, and obtain assistance from post-graduate students skilled in the application of statistical analysis. In their cognitive interaction with the data, as well as with the other students, assistants and lecturers in the lab, the students were enabled to construct their own knowledge, associating it with prior knowledge, thereby attaining real understanding of the issues. A learning environment in which constructivism comes into practice was thus created.

South African students are often those with the best basic knowledge in foreign laboratories. However, when faced with problem-solving, they often lack the basic reasoning and logical skills of their fellow researchers (Ward 2001). This comes from years of being spoon-fed, and expected only to regurgitate the information that has been given to them. Apparently this is not a phenomenon unique to South Africa. In the USA Tinto (1987) found that many students cannot apply the information they obtained in courses to common, every-day situations, and Daloz (1987) concluded from his studies that most students cannot make comparative relationships between the factual content they have learnt. Lord (1998) speculates that this might be a result of the way they are taught, and suggests that we use constructivism in Biology instruction, and drastically modify the way we teach. In this course we wanted to expose the first-year students to a new approach in lecture facilitation, and observe and analyse their response to it.

Firstly no textbook was prescribed, not only because no single textbook covering all these topics exists, but also because we did not want the students to memorise the facts and repeat them without gaining new insight. Furthermore no lecture notes was handed out, and an information sheet, with applicable websites and general books concerning the various topics, was provided. After much concern, and frequent and urgent requests from the students, a CD-ROM was compiled providing the information that appeared on the PowerPoint projection screen and the overhead transparencies. A few copies of the CD-ROM were made available at the Reserved Material section of the University library, where they could be borrowed by the students. The information was also put onto the University's computer network, and the students were provided with information on how to access the information there. Interestingly, less than 20 students made use of the CD-ROM copies in the library, while approximately 450 students downloaded the information from the computer network within the first week of availability. This is in accordance with the results obtained after analysis of the impact of a CD-ROM supplied with the Biology textbook (see Chapter 3). Apparently, mainly due to hardware inefficiencies and software incompatibilities, a CD-ROM provides a rather restricted information medium in comparison to the inter- and intranet.

4.6 PROCESS ACTIVITIES / IMPLEMENTATION

4.6.1 Theoretical lectures

The topics chosen for the eight lectures had imaginative and striking titles, appealing to the interest of students. They were as follows (also see Addendum 3)

Lecture 1: *Did the dinosaurs all go extinct at once?* A few projections of pictures from the movies led the students' minds into the world of "Jurassic Park" and the BBC series "Walking with dinosaurs". Theories surrounding the extinction of dinosaurs were discussed, and the scientific method, subjective versus objective knowledge, hypothesis testing versus theory, induction versus hypothetico-deductivism, as well as naïve falsification were all illustrated by elaboration of this example.

Lecture 2: *The discovery of DNA – the victory of theory over hard work.* The race to discover DNA was described, and seen as a struggle between empiricists and theorists. The application of both induction and hypothetico-deduction was demonstrated, while formulation of a null-hypothesis was illustrated.

Lecture 3: *Magic Johnson, Kenyan prostitutes, condoms and the HIV/AIDS controversy.* This lecture covered the issue of the burden of proof. AIDS statistics, the functioning of the HIV virus, and establishing a connection between the HIV virus and AIDS were discussed. Campaigns promoting the use of condoms were criticized. Students were drawn into discussion by inviting four of them onto the stage, handing out condoms to two of them, and letting the other two fill the condoms with water. This illustrated to them how condoms are tested in a factory, and suggestions were offered by the students whether this test can be accepted as an indication of condom efficiency against infection by the HIV virus. It was emphasised that although we do not know all the answers, science is still doing work, and the search is going on.

Lecture 4: *Would Jesse Owens (Olympic gold medal 1936) beat Maurice Greene (Olympic Gold Medal 2000)?* This lecture was used to teach the value of contemporaneous controls and replication. The fundamental rule of experimentation, the value of replication, pseudo-replication, experimental design and reliability were discussed.

Lecture 5: *Do men have bigger brains than women?* The issue of inherent biases and prejudice in science was highlighted. Differentiating between cause and effect, the existence of pseudo-correlations, bias by statistical artefact, inappropriate comparison, confounding factors and Simpson's paradox were illustrated in this lecture.

Lecture 6: *Gay genes and the Human Genome project.* The issues of "hard" scientific evidence and environmental vs. genetic control of behaviour were discussed in this lecture. The gay gene concept and human genome project assume strong genetic control, and give little credit to environmental influence on development. These arguments fit into the bigger picture of scientific conflict over reductionism and holism.

Lecture 7: *Did O.J.Simpson kill his wife?* Another relevant case in which the issues of scientific evidence (DNA), parsimony, Occam's razor and the value of scientific evidence in the world at large were discussed. The interesting way in which science was used in the O.J.Simpson trials were illustrated, as well as the nature of the PCR technique, and technological versus scientific revolution. The formulation of null and alternative hypotheses, and types of error resulting from unreliable scientific evidence were discussed. It was emphasised that science can only do work if it is "translated" into a form which people can understand.

Lecture 8: *Is conservation biology science or sociology?* Problems of laboratory experiments, field experiments, natural experiments and uncontrolled observations were highlighted with applicable case studies. The need to combine science with public policy in order to make science worthwhile was discussed in an illustrative conclusion.

The lectures thus showed the students how many of the skills fundamental to doing science are harnessed to understand the nature of scientific problems, and covered the most important philosophical issues.

4.6.2 Practical Laboratory Sessions

The two three-hour lab sessions were devoted to introducing the students to the collection and processing of real data. Because of the limited time available, as well as the need to keep costs low, practicals were optimised in the following way:

(a) The first hour was spent on an introductory lecture explaining how the data was to be collected and processed, and on what logical principles the statistical formulae were based.

(b) The only supplementary equipment that had to be bought to carry out the practicals were measuring tapes (for collection of the data) and cardboard sheets (for playing a card game). Moreover, because the students worked in groups and pairs, the total cost of this equipment could be minimized to less than R400.

(c) Most of the postgraduate students in Nature Conservation and Ecology acted as student assistants (3-4 per lab) to aid the students where needed during the lab sessions. These students were thoroughly informed and prepared for the laborious task awaiting them, and lived up to expectations, fulfilling the task with enthusiasm.

(d) Practical assignments were handed in on the Monday after the Friday's lab session, and marked by the lab assistants.

First Practical Session:

The first practical session dealt with the *description of data*. Students were introduced to different types of data, as well as the concepts of a variable, mean, median and mode. Measures of variability, i.e. standard deviation and coefficient of variation were explained, and with that as background they had to collect their own data and present it graphically in five different ways.

The variables that the students dealt with were the height, head circumference and fist circumference of different people. They worked together in pairs, and formed groups to assemble data of 15 men and 15 women. The different groups were formed by students sharing a lab bench. All these students would therefore have the same data on which their analyses and graphs were based. They measured one another's head, fist circumference and height, indicating the gender from which the data was obtained. Data was thence graphically displayed by (a) a box- and whiskers plot, (b) a histogram, (c) a mean-and standard deviation plot, (d) a scatter plot, and (e) a plot for the optimal sample size. Because the mathematical formulae were given to them, and they had to analyse the data by application of these formulae and the use of their standard pocket calculators, they could get a good grasp of the steps involved in data processing. The same data was used time and again for both practicals, and the students could really get hands-on experience in the manipulation of data.

Second Practical Session:

The second practical session dealt with *testing hypotheses and correlations*. Two tasks were given, each dealing with the same data as previously, with a few questions concerning the results to ensure that the students gained insight into the problem while obtaining the solution.

First they were introduced to the concept of probability theory, and the formulation of a null hypothesis. Using the information gained from the data to formulate a statistical strategy was the objective. A very simple card game was devised and played in pairs to test for a statistically significant difference between two sets of measured data.

In the second task the relationship between two variables was calculated, using the same data as before. Determination of a correlation coefficient, and plotting of a best-fit line by eye, as well as a calculated regression line, was carried out.

Again all formulae had to be calculated by hand, implying that the students could grasp eventually which mathematical functions, and how many iterations thereof, were applied in the statistical analysis of their data. The reasoning behind the mathematical manipulation of the data also became evident.

Survey: The men in the class had to design a survey to examine condom use by Maties students, while the women's survey involved a previous paper by Martha McClintock (1971), regarding menstrual synchrony and suppression among women living together in a college dormitory. As time did not allow them to carry out the survey in practice, they had to answer specific questions on the design of their survey, on which they would then be assessed.

4.7 ASSESSMENT

The students' work was assessed in a single theoretical examination with multiple choice questions. A written assignment on the practical work was handed in after the last practical session, and a written report on a survey that had to be planned in all stages up to the implementation phase, had to be completed before the end of the term. As these lectures form part of an interdisciplinary module, we were not free to assess the students as we desired. No assessment of laboratory work was carried out in the other sections of Biology 124 - resultantly the practical lab work was not used in the students' final assessment, although the assignments and reports were evaluated and given a mark. To motivate students to do their best with the assignments, these marks were used in a positive way, i.e. if a student performed poorly in his/her theoretical examination the practical mark (assignment and report) would be taken into consideration for determination of the final mark.

4.8 FEEDBACK

In the penultimate week of classes of the first semester a questionnaire focusing on the section *How do we do Biology?* was completed by the first-year Biology students. I designed this questionnaire to gain insight into specific aspects of concern regarding our new approach to statistics teaching. During the last practical session a general evaluation sheet for all sections of the module was completed by the same first-year students. This standard evaluation sheet is compiled by Uni-Ed at the University of Stellenbosch, and completed after every course. Information gained is summarized in Figures 1 and 2.

Analysis of the students' feedback immediately revealed a marked positive change in their attitude towards the statistical section of the module (Figure 1). There was a conspicuous increase in the number of students who (a) liked this section most, (b) found it most informing, (c) thought it should be extended, (d) found it easy, and (e) found the practicals applicable. Furthermore fewer students (a) found it difficult, (b) liked the statistics least, (c) thought it should be down-scaled, and (d) found the work too much.

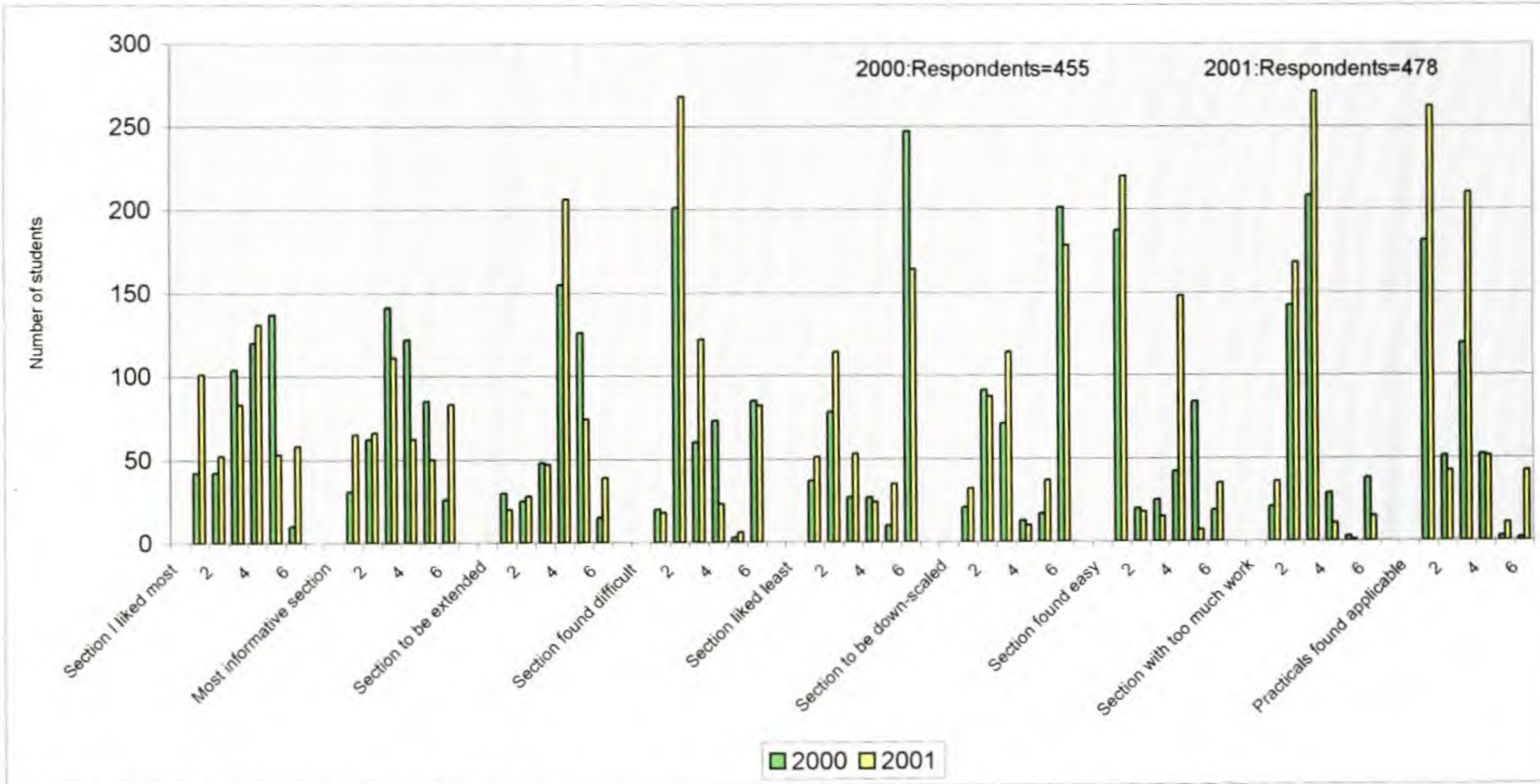


Figure 2: Students' evaluation of different sections of Biology 124, showing relation of Statistical Section (6) *How do we do Biology?* to other sections (1) Cytology, (2) Biochemistry, (3) Microbiology, (4) Genetics, (5) Evolution. Number of respondents: 455 (in 2000) and 478 (in 2001).

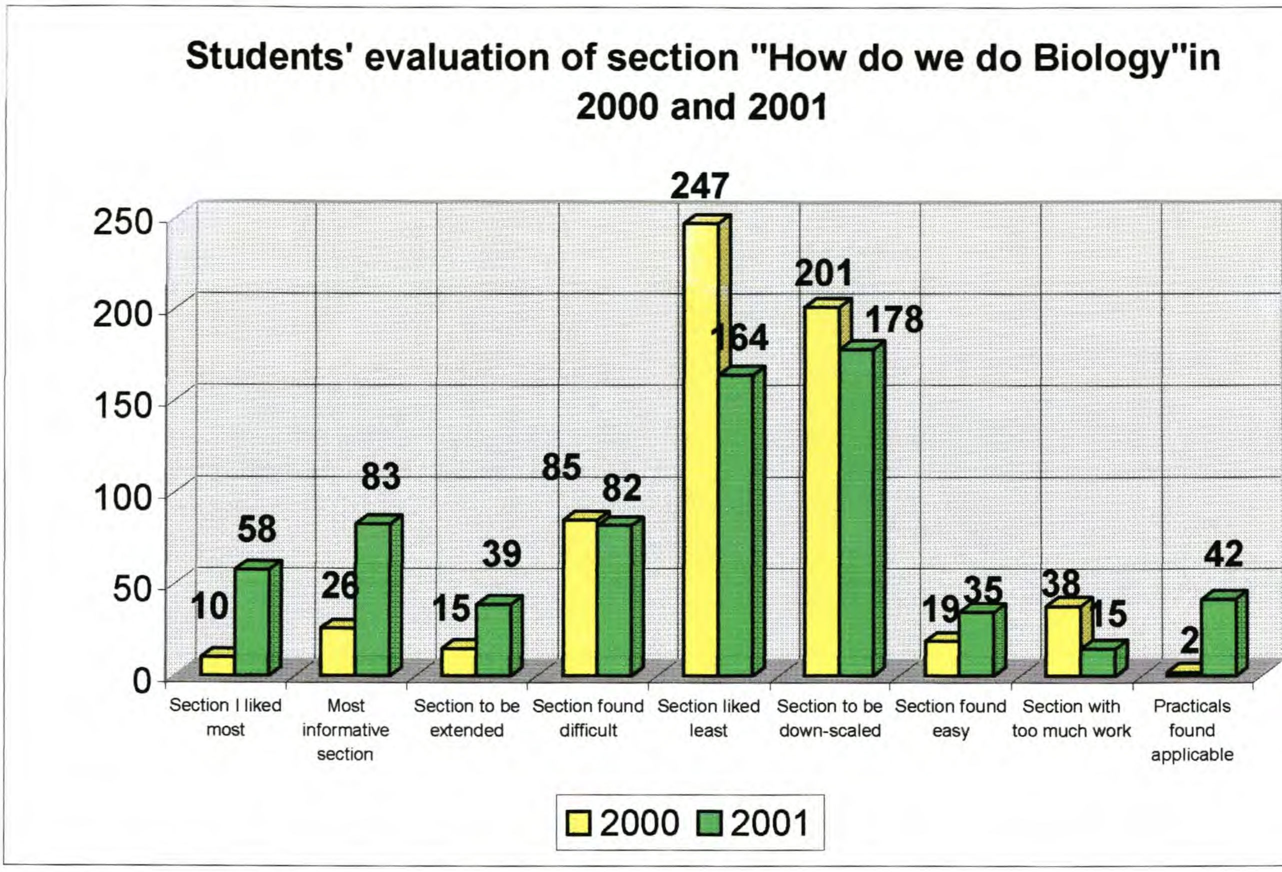


Figure 1 : Students' evaluation of the Statistics section of Biology 124 in 2000 & 2001.

When analysing the students' evaluation of the statistics section in relation to the other sections, both for 2000 and 2001 (Figure 2), the following can be deduced: The statistics section was previously the one which the students (a) liked least, (b) found least informative, (c) least wanted to be extended and most to be down-scaled , and (d) found the practicals least applicable. After completion of the new *How do we do Biology?* course they rated it as (a) the second most informative section, and (b) fourth when looking at the section which they liked most, and (c) thought should be extended. It was rated as the third most difficult/easy section, and the applicability of the practicals was rated fourth. Although it was still not the most popular section of the module, the students did not find the work too much, and only 82 (15%) found the work difficult.

A surprising phenomenon was revealed when comparing popularity (evaluated as being "easy" and "most liked") with examination marks (Figure 3) for a section. In

2000 students rated Microbiology and Genetics as "most liked" sections, although their average marks for these sections were only 48% and 59%, making them the second and fourth lowest averages. The lowest average was for Cytology which they evaluated as "easiest". The same occurred in 2001 when Cytology was again rated as the "easiest" section, while their average was second lowest (49%). They also liked Cytology second most, and Genetics most, while getting the second and fourth lowest (53%) average marks for these sections.

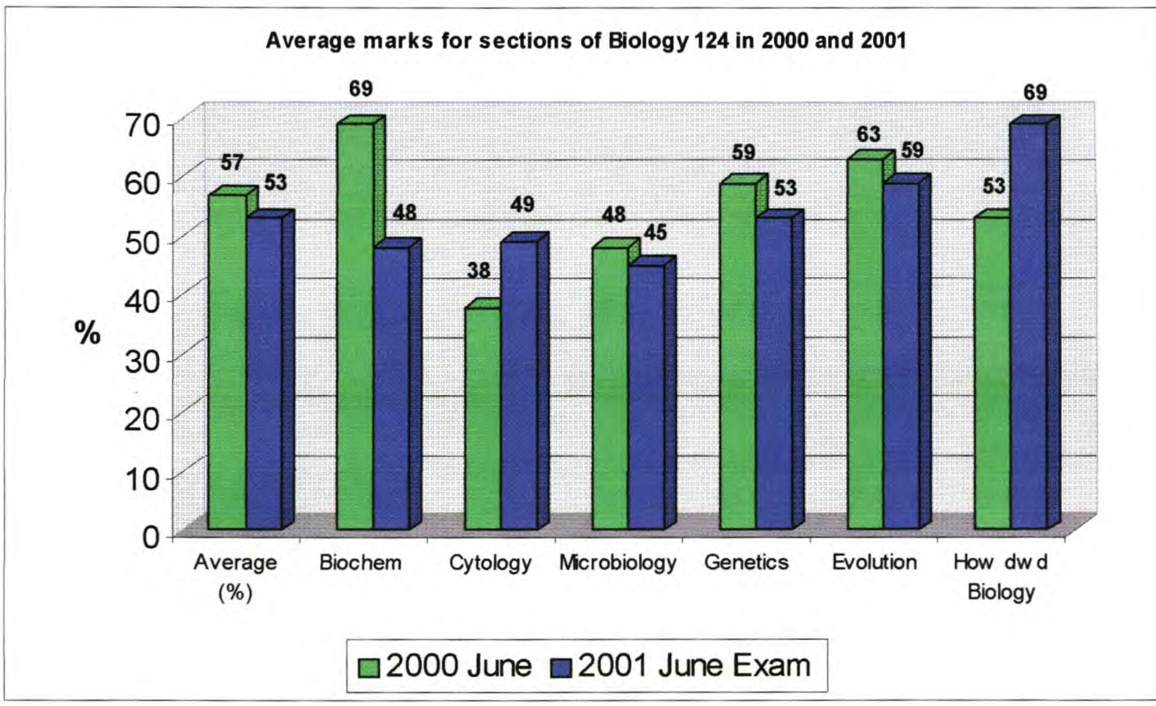
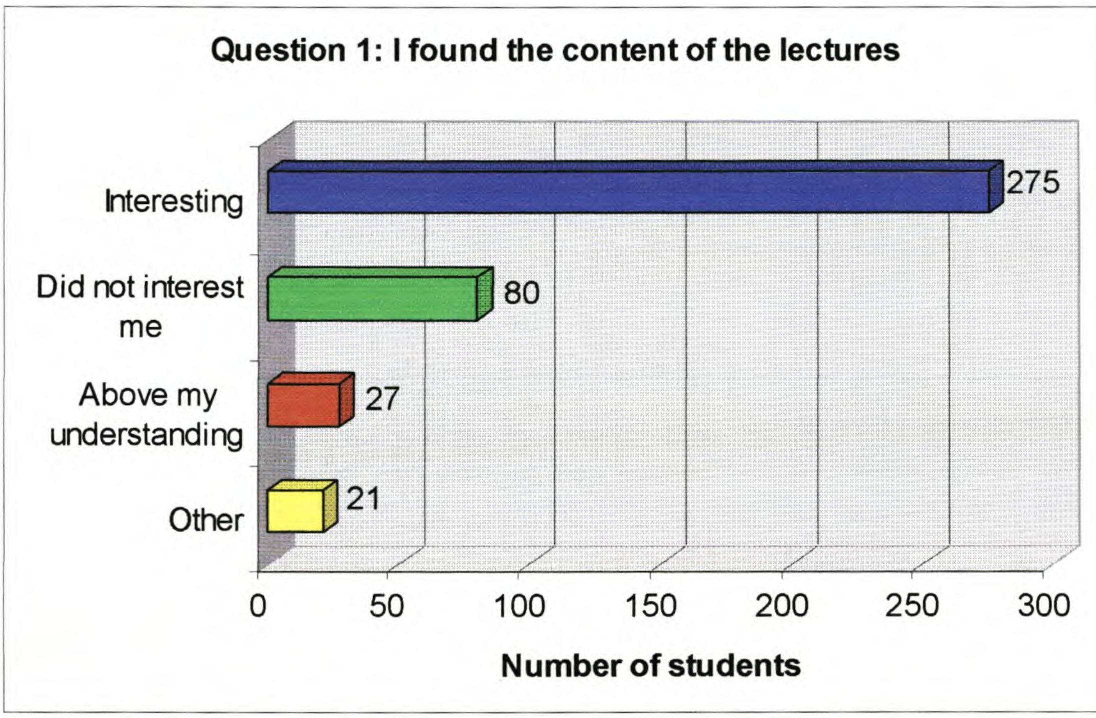


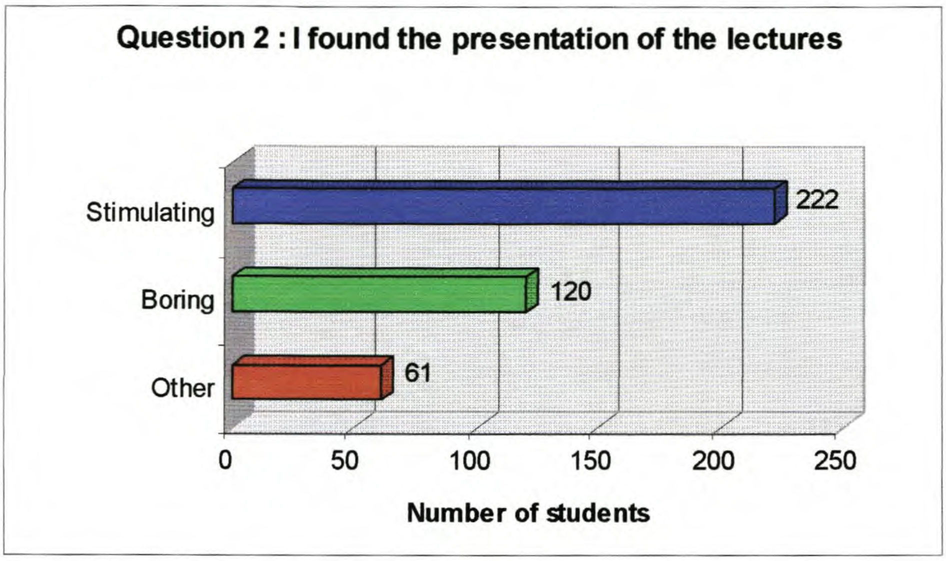
Figure 3 : Average percentage for module and sections of module Biology 124.

There is evidently no direct correlation between the students' opinion of the module and the marks they scored for it. Both evaluation sheets were completed after the first test series, but before the first examination . As *How do we do Biology?* is only facilitated in the last few weeks of the semester, no assessment of this section of the module was done before completion of the evaluation sheets. Students therefore did not have knowledge of their ability to gain marks in this section, which was only assessed in the June examination. It could be interesting to see if students' evaluation of a course would differ when evaluation sheets are completed after obtaining their examination results.

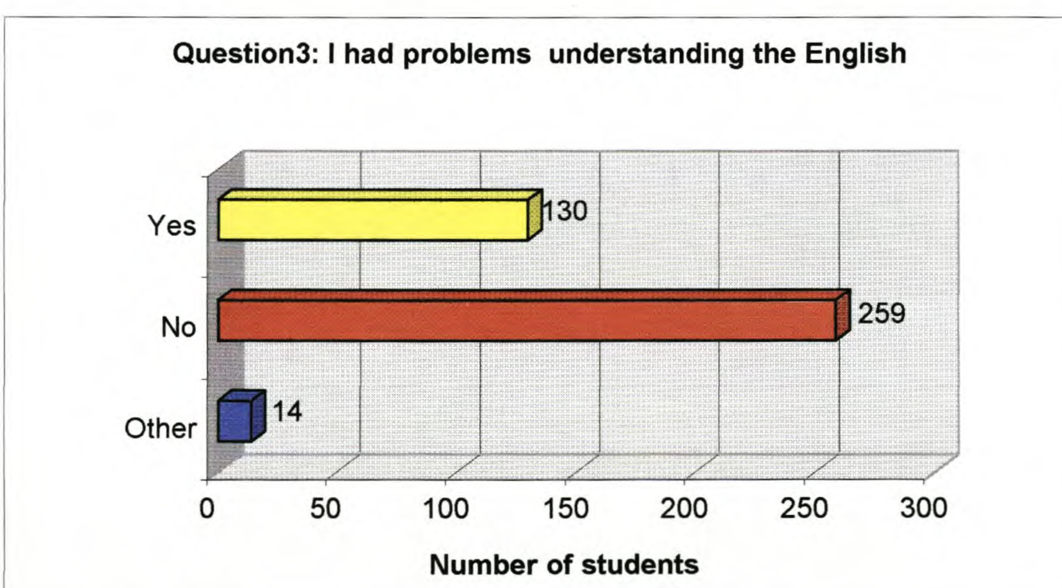
Information obtained by questionnaire regarding specific aspects of our new approach to first-year statistics teaching can be graphically summarized as follows (**Question 1** to **Question 5** refer to the questions and possible answers on the questionnaire (see Addendum 1: Section C)):



Most students were interested in the topics discussed, and only a few found it incomprehensible (Question 1). Some students commented that they found the content confusing, pointless and irrelevant. Others wanted more detailed explanation of the content. On the other hand students used words like 'inspiring' and 'fresh' in their description of the lecture content.

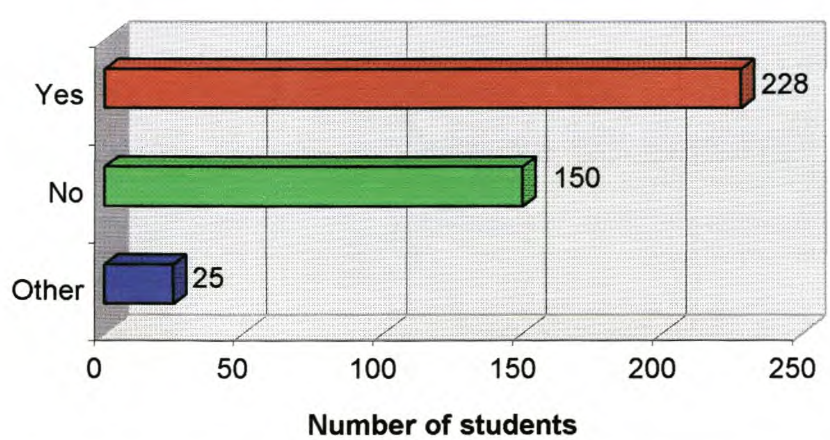


Although the majority of students found the presentation of the lectures stimulating (Question 2), a few commented that Prof. Ward moved too fast for them to follow, resulting in confusion and frustration. This may be a general complaint of students in their first year at university. Still others regarded the presentation as 'professional' and 'informative'. The students who found it 'boring' mostly commented that they were not interested in talking about science and not doing any experiments – which directs us to a great educational need! A philosophical approach to science has long been neglected in our entire educational system.



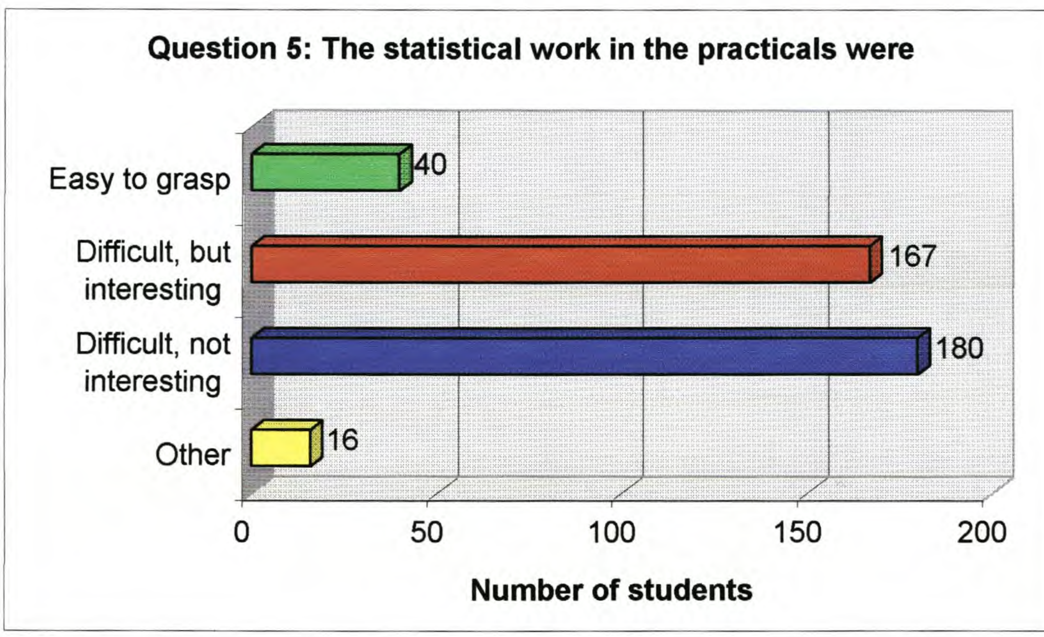
As the University of Stellenbosch is committed to a language-friendly first-year curriculum in Biological Sciences, there was great concern about the students' reaction to classes being facilitated only in English. Most students (65%) were not disadvantaged by this, and some commented that since all overhead displays were both in Afrikaans and English, it did not influence them (Question 3). However, four students did remark that this is supposed to be an Afrikaans university, and authorities should 'get someone' to teach in Afrikaans. As it would have been much more detrimental to get an Afrikaans lecturer without Prof. Ward's philosophical approach to the course, the language problem was to my opinion solved satisfactorily.

Question 4: The practicals related well to the theory.



Many students (almost 60%) felt that they understood the theoretical classes better after completion of the practical sessions (Question 4). The majority (86%) found the content difficult (Question 5), and there was an overwhelming feeling that the practical sessions were too long and involved too much tedious work. This was concluded from personal communication with the students, as well as from their response to the questionnaire (Question 6). It is true that the practical sessions started with an hour of much-needed instruction, before the students actually started in the lab. This implied that for most students the practical sessions took 3 to 4 hours to complete. However, the time-table specifies a 3 hour slot for Biology practicals – the students were simply used to shorter practicals in the other sections of the module. The work was tedious, as we tried to demonstrate to them the steps followed in statistical analyses without the application of computer software.

The survey that had to be completed as a home assignment was generally done with great enthusiasm, and as time did not allow them to actually carry out the survey, it was just expected of them to describe the steps followed, and the precautions taken in the execution of the survey. It was encouraging that many students asked us if they could actually carry out the survey, as they were really interested in the data.



Statistics is not easily grasped by people who have never been exposed to the mental processes involved in such analyses. Furthermore, for many people all cognitive processes seem to cease when confronted with any problem involving mathematical equations. Statistics is not a subject offered by South African schools, and for most first-year students it was therefore an abrupt initiation into the world of statistics in science. Many students found the statistical analyses simply too difficult and too much work to carry out in two practical sessions, although the majority of students still found it either easy, or interesting, albeit difficult.

In their remarks on specific aspects of the theoretical or practical part of the section "How do we do Biology" the students' opinion varied to such an extent that it seems incredible that they are talking about the same lectures! Comments varied from excessively negative - "Extremely boring, a complete waste of time" - to almost lyrical in praise – "Interesting and stimulating", "very cool", "I loved it!", "For the first time I started to THINK about Biology : Wow!", "Good to see theory in practice – will help me in research one day", and "I enjoyed both the lectures and practicals immensely, and would like to compliment Prof. Ward on his choice of material and presentations."

Many students were worried about the lack of a textbook and class notes, and did not know what to expect in the examinations. This was, however, addressed in the compilation of the previously-mentioned CD-ROM which contained information identical to all overhead projections. As indicated earlier (see Objectives/Learning outcomes) the university's computer network provided a much more accessible medium than the CD-ROM at the library.

Great caution should be practised when taking students' feedback of a course into consideration in the future planning of that course. The main task is not to improve enjoyment and popularity of programmes, but to improve the level to which learning is produced, and to enhance the facilitation of quality learning. Enjoyment may follow implicitly once powerful learning environments are created and students start achieving success by constructing their own knowledge and making their own discoveries. However, motivation for alterations in a programme should never be the production of a popular or "likeable" course.

4.9 REFLECTION

'If the goal of our instruction is to develop students who are enthused about biology and really understand the material, we need to drastically modify the way we teach' (Lord 1998). Being involved in a novel first-year curriculum, still fraught with growing-pains, provided us as biology teachers with an ideal platform to promote various new approaches to lecture facilitation. This involved mainly the application of information technology both in the input provided by the lecturer and the output expected from the student. Students were expected to construct their own knowledge from various sources, and be actively involved in the acquisitioning of a philosophical approach to scientific reasoning.
Four separate aspects were ultimately addressed in the facilitation of the statistics section of the module Biology 124:
(a) Lectures were facilitated under the learning paradigm, with a holistic approach to teaching and learning, and an integration of theoretical and practical sessions.
(b) Practical sessions were facilitated using constructivist-based activities and cooperative learning, thereby creating powerful learning environments.
(c) Lecture facilitation for an extremely large class was promoted by innovatively applying the available technology and support staff and students.
(d) New information technology was applied in the compilation of a CD-ROM, and in the availability of this information on the University's computer network, to provide students with a summary of the main discussions in the lectures and practicals.

Future modification of the lecture series should firstly involve mainly the practical sessions. It seems imperative that a third practical session should be allocated to this section, making the workload in each session less, and enabling the students to finish the work within three hours. The survey they designed could then also be carried out, and experience gained in such data accumulation and analysis.

My suggestion is also that the practical mark given for the survey and practical assignments should be considered for the students' final mark, as this will aid as further motivation in the practical sessions.

In the event of the curriculum planning committee considering to revert to the previous statistics course I will strongly recommend that they take into account the improvement in the students' marks, their positive experience of the lectures, and most important, the innovative way in which intriguing subjects are harnessed to illustrate in a holistic way the nature of scientific problems and problem-solving.

The time for spoon-feeding belongs to the past. The mission is to produce quality learning, and the quality of our exiting students will be the criteria for our success. This new approach to statistics teaching may inspire the initial awakening of our first-year students to the powerful learning environment that an institute of higher education can be.

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CHAPTER 5

How do we do Biology? A video-enhanced self-study guide for first-year students.

PART 1: COMPILING THE SELF-STUDY PACKAGE
PART 2: THE SELF-STUDY PACKAGE (SEE ADDENDUM 3)

5.1 INTRODUCTION

Mathematics seems to have astonishing power to tell us how things work, why things are the way they are, and what the universe would tell us 'if we could only learn to listen' (Cole 1998). The accumulation, manipulation and comprehension of data is becoming increasingly indispensable in science. The scientist's search for meaning is invalidated without the power of statistics. Yet students in the Biological Sciences are mostly introduced to statistics only in their post-graduate years. Nolan and Speed (1999) describe their own and other attempts at designing new models for teaching statistics.

Therefore, in the new programmes of learning implemented at the University of Stellenbosch in 2000, a multidisciplinary module Biology 124 was designed to include an introduction to statistics to first-year students in the Biological Sciences (together with their introduction to the disciplines of cell biology, biochemistry, microbiology, genetics and zoology).

5.2 WHY A SELF-STUDY PACKAGE?

Subject area, learner profile, influencing factors

In the first year of implementation of the new interdisciplinary module Biology 124 the results for the statistics section were extremely disappointing, both in student marks and feedback. The score was the second lowest of the six parts of the module, and the feedback was exceedingly negative. Statistics was rated as the section of the module that they enjoyed least, found least interesting, experienced as very difficult, and regarded should be down-scaled (see Chapter 4). A new *modus operandi* therefore had to be devised.

A probable solution was provided by Prof. Ward of the Department of Nature Conservation (University Stellenbosch). His introductory statistics series, which he aptly calls *How do we do Biology?,* introduces first-year students to interesting case studies in which statistics have provided the invaluable tool. The lectures have catching titles, which would appeal to students, resulting in a captive audience. The aim of the lecture series was not to teach students statistical formulae, but rather to make them realize that biology is exciting, that scientific progress occurs in various ways, and that scientific results do not need to be clear cut to contribute to progress in science.

The learner group consisted of 570 first-year biology students following different programmes in Biological Sciences, Agriculture, Forestry, Life Sciences, Consumer Science and Human Movement Science. Students all had mathematics as a matric subject, but not all had both biology and science up to the same level. As the School of Biological Sciences has a "language friendly" approach to first-year teaching, all lectures are facilitated both in Afrikaans and English, in two different lecture halls, by two different lecturers. Practical sessions of three to four hours each were facilitated on two afternoons and one morning per week.

Due to the specific lecture content, the objectives of the course and the expectations of the students, it was decided that for this section of the module Biology 124 the lectures would be facilitated by Prof. Ward only. This meant that the Afrikaans and English groups that were facilitated simultaneously now had to be merged into one group of approximately 340 students (the rest of the students were in a separate Afrikaans group). Furthermore, due to the full time-table of first-year students, the third group could not be merged with the other two, implying that Prof. Ward had to facilitate every lecture on two occasions. The language of instruction would be English, and the compromise of the Afrikaans-speaking students to this regard would be compensated for by the use of technology. All lectures were facilitated as PowerPoint presentations, one in English and one in Afrikaans, using data projectors and two screens. Although the language of instruction would be English, students were free to converse with Prof. Ward in Afrikaans. Tests and examinations would be in both languages, and assignments and reports could be completed in the language of choice.

Another major obstacle was provided by the lack of a lecture hall big enough for such a large student group. The only available venue was the concert hall in the Conservatoire of Music, which can accommodate 530 people. This was in many ways not the optimal choice, as there was a complete lack of projection screens, electric power points, writing desks for the students, and neither a podium nor a microphone system for the lecturer.

However, all these problems were solved in time. The biggest obstacle from the students' perspective was the lack of both a textbook and class notes. No textbook was prescribed, firstly because no single textbook covering all these topics exists, and secondly because we wanted to move away from the traditional regurgitation of memorized facts by spoon-fed students. The lecture content would provide a holistic approach to statistical thinking, and students were therefore encouraged to construct their own knowledge from both the theoretical lectures and the practical sessions. Reference to websites, and general science books to consult, was provided.

The above-mentioned aspects therefore clearly indicate that from the start this section of the module was fraught with problems. The content of the lectures was met with apprehension by colleagues, and in many ways the first-year biology students were exposed to a new approach in lecture facilitation. From the students' point of view the major obstacles were the following:

- Lectures were facilitated in the second language of the majority of students.
- Statistics is a subject completely new to many of them – few South African schools offer Statistics as a matric subject.
- No textbook was available.
- No class notes were handed out.
- The students had to follow this course in their first semester of first-year studies, while already coping with the normal first-year adaptation problems.

Integration of all these factors gave cause for great concern about the practicability of the lecture series. Being directly involved in the coordination of the module, various options were considered. The advantages of giving students access to a repetition of the full content of the lectures overshadowed all other options. With the emphasis on digitizing information, increased access and visibility on the university's intranet (Web-CT) and the new "e-campus" (Die Matie 2001) proposed by the University of Stellenbosch, this idea was enhanced even further. Consequently I made video-recordings of the entire lecture series, to be made available to students for study purposes.

The advantages of a complete study-guide that includes the video recordings of the lectures, formalized later. Further benefits attended with the provision of a study-guide also became obvious. For example, students who did not pass the module Biology 124 in the previous year, and have to repeat the examinations without attending the lectures in the current year, would hereby have direct insight into the activities in the lecture hall. With the new programmes of learning being adapted from year to year, such 'repeater' students will be able to 'attend' the lectures on video in their own time, i.e. asynchronously. Furthermore, other academic staff members and post-graduate students revealed great interest in the lecture series upon hearing of the titles and philosophical approach to the content. A study-guide with included video-recordings would enable such individuals to gain insight in their own time (see "Who should use this study-guide" in the attached study-guide (Addendum 3)).

5.3 TYPE OF PACKAGE

Approach followed and Nature of materials

To be a truly complete study-guide, containing and encompassing all aspects of the section *How do we do Biology?,* implied that it had to be a multimedia package. Firstly all lectures, as well as the theoretical part of the practical sessions were recorded on video, using a digital video camera. The videos were edited digitally, and complete video footage was eventually copied to DVD. Being able to listen repeatedly to the lectures provided the students who had problems following the lectures in English with an appropriate and user-friendly tool, thereby enabling them to make sense of the lecture content in their own time and at their own pace.

Copies of the PowerPoint presentations of all lectures, both in Afrikaans and in English were obtained from Prof. Ward, who kindly gave permission to use them for this project. These presentations were copied onto a DVD, and provided the students with a summative version of the content of the lectures. As both Afrikaans and English students could be accommodated, this helped to overcome the obstacle provided by the language preference of the majority of students. Students could furthermore make paper copies of the presentations in Afrikaans and English to help them study the main points of each lecture. The Afrikaans version of each lecture was more concise, being used for overhead transparencies, while the more elaborate English version contained photographs, graphs and other figures.

Although no single textbook was prescribed, various references are included in the study-guide. Both books and internet sources should be consulted, and the students are given a good indication of the variety of books on these topics, providing some “popular scientific” reading material many first-year students did not know existed.

The study-guide was developed as a wrap-around package, to be used in conjunction with the lectures and practical sessions, which at this stage require obligatory attendance. However, little adaptation is needed to develop this study-guide into a stand-alone package. Adaptation of the practical sessions, e.g. not involving group work, but still requiring a written report, could eliminate the need for attendance of both lectures and practical sessions. The current inclusion of an assignment involving a survey that has to be designed, but not carried out in practice, provides a good starting point for adaptation.

By using this self-study package the module Biology 124 could in fact become a distance learning course, including this guide as a stand-alone package.

5.4 FORMAT OF STUDY-GUIDE

Justification for type of media/technology used

The study-guide was designed with as little as possible material printed out, and most of the content provided in electronic form. The printed material consists mostly of instructions on how to use the study-guide, with reference to the content of individual lectures, and how to access the information for different purposes.

The different lectures consist of an almost monotonous repetition of instructions. The purpose of designing the lectures according to a standard template was that any lecture could be accessed in any order, according to preference or interest, without the need to go back every time to an explanation of how every lecture should be worked through. Therefore the same headings, icons and style are used in the description of every lecture, resulting in a 'template style' of presentation.

The Afrikaans version of the PowerPoint presentation was most concise, and provided the "Main Points" of every lecture, to be used as both an introductory overview and summary for revision. The English version included more graphical information and data, and could therefore be used for both detailed contents and revision. The video recordings provided the most complete version of the lecture, being an exact account of the events in the lecture hall.

All information was copied to DVD, with the different versions of PowerPoint presentations, the video footage and the tests hyperlinked to a Web-page front-end.

5.5 METHODOLOGY

At this stage, and with the current focus on class attendance in the BSc programmes, the study package will be a choice component of the course. Students will be able to study it at home, or in the computer service areas on campus. Students repeating the course will obviously use it as their only source of information, but other first-year students will use it supplementary to their attended lectures.

Were it possible to provide video footage of lectures on the university's intranet as an option to class attendance, the scenery would evidently change completely. In such an event some students may prefer only to make use of the lecture on video, while others would still prefer the live version provided by class attendance. The greatest benefit in the latter case would be that students' questions could be answered directly, time permitting. My observation of lectures, however, revealed that little or no interaction existed between student and lecturer in such large classes. Students watching only the video, instead of attending lectures, could always contact Prof. Ward by electronic mail, a facility that is accessible to all students on campus. Providing access to lectures on video may also eliminate the necessity to repeat lectures for different groups of students because of the size of the class or problems with the timetable. A single facilitation session of every lecture would also free the lecturer, giving him/her more time for student consultation. This aspect will probably be exploited in the future, providing sufficient extension of the available IT facilities. At the moment storage server capacity is insufficient to allow for such large files (the video recordings vary from 380-470 megabyte each) to be accessed by large numbers of students on the University's computer network.

5.6 PROCESSES INVOLVED IN DESIGN AND PRODUCTION

5.6.1 Video recordings

Six of the lectures and both practical sessions were recorded using either a Panasonic AG-EZ1 or Panasonic NV-DX100 digital video camera. An external rifle microphone was attached to the camera to obtain optimal sound recording. No additional lighting equipment was used. Digital recordings were edited with Adobe Premiere 6.0.

5.6.2 Electronic information

Digital video recordings were edited with Adobe Premiere 6.0. All video recordings were copied onto Digital Video Disk (DVD). PowerPoint presentations in Afrikaans and in English were copied onto the same DVD, as well as the extra information like tests. Due to the storage capacity of a DVD, only one disc was needed for all the separate files, which can be accessed from a Web-page front-end.

5.6.3 Paper copy of guide

A self-study guide was prepared with a simple and user-friendly approach to its application. The guide gives clear instructions on the "who, where and how" of the material to be studied. An assignment, as well as a section for self-evaluation, is included. Ample material to read and think about is provided.

5.6.4 Self-study package

The self-study guide, together with the DVD, form a self-study package that can be used as either a wrap-around package to support the existing lectures of *How do we do Biology?*, or a stand-alone package to be used instead of attending the normal lectures.

5.7 CRITICAL REFLECTION

5.7.1 Recording of video material

In recording the lectures on video it became clear that it is no easy task to give an interesting account of what is happening in a lecture hall by simply capturing it on video. The following aspects were most conspicuous:

- Lecturers are not naturally performers or actors, and a video-recording of a normal lecture can become quite boring to sit and watch on a screen
- There are often long silent pauses, when students are expected to write something down, or when the lecturer walks around, e.g. to change overhead transparencies
- The normal lighting in a lecture hall is insufficient to make good-quality video-recordings. Many lecturers dim the lights, or even put them out completely, when giving a PowerPoint presentation. This implies that such video-recording contains mostly or only the lecturer's voice (audio) during these dark minutes. Especially in this case, where the Endler Hall allowed

for only bright lights or total darkness, much of the footage was shot in semi-darkness.

- Where lectures are generally video-taped, lecture-halls are beginning to look like broadcasting studios, and lecturers have to be prepared to be an entertainer as well as a facilitator.

5.7.2 Access to IT facilities

One of the biggest problems with electronic media is the provision of access to those media. The existence of a CD-ROM or DVD does not implicitly indicate its use. This was specifically indicated by the questionnaires completed by the first-year biology students. In this class only 25% of the class used the CD-ROM, mostly because the computers available to them did not contain CD-ROM drives (see Chapter 3).

It was also found (Ward 2001) that the minority of students made use of CD-ROMS to be borrowed at the library, once they could access the information on Web-CT. The internet and intranet appear to be the most powerful tool in information accessibility and availability. This may change once more students have access to their own computers. At the moment computer facilities are made available to the students in the form of Computer User's Areas (CUA). The 10:1 students:computer ratio of 2001 is projected to change to 5:1 in 2002 (Die Matie 2001). All registered students can gain access to a CUA, and network access points are also provided in students' residence rooms on payments of a specified levy. If students were provided with notebook computers ("laptops") as is the case in many universities in the USA (Sargeant 1997) the scene may change once again, providing that a powerful local network can be accessed everywhere on campus by all these notebook computers.

5.8 THE FUTURE

Information Technology has opened new and fundamentally different options for improving teaching and learning. It allows teachers and students to project themselves across space and time, to locales and circumstances that best meet learner needs, with substantially less degradation than was possible with predecessor technologies.

It thereby also constitutes a paradigm shift. Information technology is a transformation agent affecting everything. According to Tuller (1997) the essential process of higher education is the transformation of information into knowledge, and knowledge into insight. The technology catalyzing such enormous changes in how we manage information, therefore has immense implications for higher education.

According to Massy (1997) universities have tried various stratagems for mitigating the difficulties associated with their handicraft methods. However, many of these approaches have engendered their own difficulties : passive rather than active learning, less access to faculty expertise and insight, and limits imposed by the printed page, television screen and teaching laboratory. Although information technology does not eliminate all these difficulties, it does reduce them substantially, thereby enabling universities to break away from the traditional teaching and learning activities. The process of breaking away is not quick or easy. Universities have only recently been distributing computing and connectivity to individual workstations on a massive scale. The task of restructuring the campus to take full advantage of the new technology remains before us.

Academic staff members often worry about "technological obsolescence". However, in education technology cannot replace the human factor. It can leverage faculty labour, changing its role from being mainly a content expert to a combination of content expert, learning process design expert, and process implementation manager. Professors will be motivators and mentors, interpreters of knowledge and "expert learners", leading the learning process by breaking the trail and setting the right personal example. Technology can leverage faculty time, but it cannot replace most human contact without significant quality losses.

Perhaps the stakeholders of higher education are caught in a paradigm paralysis (Hooker 1997). Why did we decide that mastery of the subject was less important than the time spent in the classroom? Technology allows us to focus on learning productivity, and to customize education, to provide options, and to allow students to study for as long or little as they need. It is furthermore a false assumption that it is the faculty member's responsibility to "cover the material". The technology exists for us to set objectives for the students, while allowing them to explore and drive their own learning (Hooker 1997). It should be more important that competency has been gained than how or from whom our students learn. Video-based courses with exclusive rights to their distribution and use can be delivered asynchronously. Once information is digitized, it can be delivered anywhere at any time. E-mail and the Internet furthermore provide additional and efficient means of communication and interaction between lecturer and student, again asynchronously (Hooker 1997).

Lectures on video provide an asynchronous learning environment. The incentive to develop a Virtual Information Space by means of various interfaces is enjoying high priority at the University of Stellenbosch (Scholtz & Ekermans 2002). The development of a "virtual university", and eventual creation of a global digital university, is gaining dominance in the United States of America (Hooker 1997).

One of our biggest challenges is to provide students with access to the latest information technology. And change is happening fast. Within 15 years we have had on the order of one thousand times better algorithms, five hundred thousand times more computing power per individual, and five hundred million times more mobility of information (Hock 1996). Technology competency is a competitive requirement for graduate students. According to Hooker (1997) we should be willing to invest in it. We should furthermore consider the option to require proof of technology competency and teaching excellence the same way we require PhDs in new employees.

The heart of the university's mission will not change fundamentally. Institutions will continue to manage the conversion of collections of facts and data into knowledge – information structured for innovative uses. What technology will do is transform exponentially the quality, speed and breadth of our ability to effect that conversion and to convey it to our students and the public. The challenge to educators is to preserve the essence of traditional education while changing with the times.

5.9 CONCLUSIONS

Provision of a wrap-around package such as has been developed here can be beneficiary to the students in the following ways:

- Negative effects of differences in learning style, pace, motivation and attention span can be overcome with an appropriate fusion of technology and pedagogy.
- The effect of different levels of background preparation of students attending the same class can be minimized.
- Students having problems following lectures in their second or third language are provided with a means to listen repeatedly to the same information.
- Asynchronous interaction between student and instructor provide efficient means to overcome the communication barrier of large classes.
- Large classes can be accommodated by making lecture attendance optional, with self-study from a study package and asynchronous communication via e-mail as alternatives.
- Unnecessary repetition of lectures can in this way be prevented.
- Class notes can be replaced by information on CD-ROM, DVD or Web-CT.

Information is globally being digitized. Technology enables the transmission of information. But, according to Tuller (1997) the critical process remains people interacting with other people. Technology may enable us to develop a much more participatory and collaborative society. Delivery of education through a collaborative, computer-mediated environment alter the relationship of the facilitator, the students, and the course content. Access is democratized by the many-to-many, asynchronous nature of the medium. Student input is encouraged, and teaching on-line may foster a sense of closeness between student and instructor.

The benefits of supplementing traditional lectures, where the dominant mode of delivery has been the “talking head”, with digital media are ubiquitous and overwhelming. Provision of advanced technology is, however, a prerequisite. This has major cost implications, which calls for collaboration between higher education and the private sector. Innovation, inspiration and action is needed for industry to invest in the workforce of the future, which reside in the halls of institutions of higher education.

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CHAPTER 6

Train, not strain : Assessing practical first-year biology

6.1 INTRODUCTION

This certainly is the golden age of assessment. Unlike any other time in the nation's history, student assessment is viewed as the pivotal piece around which the reform and improvement of the nation's schools turns (Roeber 1995).

With this passionate opening remark Navarrete & Gustke (1996) describe the profound transformation that student assessment is undergoing congruently with other educational shifts. They state that assessment has never before been in demand to serve such a wide range of evaluation purposes.

However, many of our traditional assessment formats are currently still at odds with the main factors underpinning successful learning. Biggs and Moore (1993) quote Shepard's statement, 'In an age of electronic learning, our tests and examinations are driven by steam, thereby accurately giving voice to the real situation at many of our institutes of higher education.

With these two opposing views the drive for a systematic re-evaluation of our current *modus operandi* concerning assessment practices and systems is aptly motivated. According to Lauvas, Havnes and Raaheim (2000) the primary focus of assessment is to encourage, direct and reinforce learning. Biggs (1999a) describes the importance of alignment and integration of teaching and learning activities with assessment practices to achieve quality learning outcomes. Assessment should therefore be designed to assist students in their learning. Moreover, innovation in assessment should never be approached lightly, because the future careers and lives of students are at stake (Race 1999).

It has been established that teaching and assessment both influence how students study and the level of understanding they reach (Entwistle 1999). While learning is regarded by some students as mainly memorizing and reproducing information, others see it as a process of transforming incoming information and ideas into their existing knowledge and experience. These two approaches to learning gave rise to the concepts of a *deep* versus a *surface approach* to learning. A third approach, namely the *strategic approach*, has been identified in learners whose study efforts are consistently geared towards achieving the highest possible grades. This indicates the pervasive influence assessment practices can have on learning and studying (Entwistle 1999).

One of the main outcomes of higher education is to encourage *critical thinking* in students, i.e. the development of complex conceptual understanding (Entwistle 1997). The research summarized by Biggs (1999a) has been amplified by Entwistle (1995, 2000) and Entwistle & Entwistle (1997), to identify five levels of understanding students reach as outcomes of learning. These include *Mentioning, Describing, Relating, Explaining and Conceiving*. Reaching deep levels of understanding can be a rewarding experience, one that is influenced by many factors. From the work of Eizenberg (1988) and Wiske (1998) can be concluded that deep learning can be promoted through *curriculum design*, *teaching* and *assessment* (Entwistle 1999). In *teaching* the enthusiasm, empathy and quality of explanation probably have the strongest effect on deep learning. Under *assessment,* factors like the tasks and techniques applied to develop and tap understanding, the feedback to clarify understanding, and the grading using qualitative criteria, all promote deep learning. Entwistle (1999) concludes that 'while we have a clear idea of how to influence levels of understanding, there are still great difficulties in achieving this ideal in practice'.

According to Bitzer (1999) and Navarette & Gustke (1996) the purposes of assessment is to :

- assist the student in the learning process by indicating strengths and achievements, as well as by providing motivation and information;

- assist the teacher in the evaluation of curriculum provision, by indicating weaknesses in the teaching programme, materials and methods, areas in need of improvement, as well as information for evaluation of the curriculum; and
- provide information for others like parents, colleagues and referrals.

Shuell (1986) remarks that it is a fundamental task of the teacher to guide students to engage in learning activities that result in achieving deep learning. According to Biggs (1999b) higher education practitioners should first decide on what they are going to teach (their objectives), and then design their teaching to match these objectives, while designing the assessment to match what has been taught. We should ensure that our objectives are buried in our assessment, and apply different techniques to attain that goal. We therefore need to move from a quantitative, measure-orientated model of assessment to one that is qualitative and standards-orientated (Biggs 1999b).

In South Africa the National Qualifications Framework (NQF) advises towards assessment criteria that are based on clearly stated outcomes and levels of achievement. Three elements of assessment are proposed :

(1) formal summative assessment, i.e. the typical year-end examination that ensures that a learner is competent to attain a certain qualification;
(2) formal continuous assessment which proposes that a learner should be assessed in a variety of ways and contexts during a specific period; and
(3) informal , formative assessment, using both self-assessment and peer-assessment in a developmental rather than a judgmental way.

In today's climate of higher accountability for ALL students, educators have moved to embrace assessment alternatives in order to capture the more significant educational outcomes required for all students. Under these alternative assessments p*erformance* assessment, *authentic* assessment and *portfolio* assessment all ask students to demonstrate specific behaviours to be assessed. According to Navarrere & Gustke (1996) performance assessment serve as a

systematic measurement of a student's acquired knowledge, thereby carrying great potential for addressing the growing demands of assessment.
As learning is an 'evolutionary process...not a revolutionary process' (Pine & Horne 1969) distributing assessment throughout the semester is likely to encourage more continuous learning effort by the students (Forsaith 2001). It is well-known that students use assessment as a basis for deciding where and when to direct their learning effort, and how much effort to make (Brown & Knight 1994). However, Tan (1992) warns that frequent testing *per se* will only improve learning, if the nature of the assessment, together with application of feedback from assessments, remedy weaknesses in the students' understanding. Variety should therefore be introduced into assessment, with a range of desired skills, including critical thinking, assessed in this way (Crooks 1988). For students to be able to improve their learning and understanding, assessment should be incremental (Brown 1999). Application of this type of "assessment driven learning" should therefore result in much greater formative assessment than the usual end-of-semester summative examination (Forsaith 2001). According to this author assessment should ideally include both formative and summative elements.

Assessment is also included in Bigg's 3P learning model, the components which are presage, process and product (Biggs 1993, 1999a). Teaching presage factors include contextual factors, students' perception of the classroom, teaching and assessment.

The influence of assessment on deep learning is therefore clear-cut. Assessment has to meet diverse requirements. Standardization and reliability are often most emphasized by institutions, while goal relevance and formative aspects are given top priority by individuals (Lauvas *et al.* 2000). Reform initiatives in assessment currently aim towards assessment that promotes learning, and that is relevant to real life situations and problems. It is imperative that we guide our students to be analytical and critical thinkers, able to apply and transfer their learning to solve novel problems (Scouller 1998). Our assessment methods should therefore both encourage the development of such abilities, and provide students with the opportunity to demonstrate these higher order abilities.

Many disciplines have been awakened by the call for innovation and transformation of assessment methods. Reports from Commerce (Forsaith 2001), Engineering (Devenish, Entwistle, Scott & Stone 1996), Technology (Mockford & Denton 1998), Biology (Lord 1998, 2001; Pitt 2000), Accounting (Tempone 2001) and others emphasize the importance of assessment in the complex matter of learning.

Implementation of new practices in assessment also calls for evaluation of the entire system, programme or curriculum in which assessment of the students' learning is carried out. Thereby the success of the learning programme, as well as its various components like syllabus, resources and teacher, can be determined (Pahad 1997, Freeman & Lewis 1998).

Assessment and evaluation are closely interconnected. Evaluation is part of the assessment process, as the evidence of a student's achievement is evaluated against the agreed standards or outcomes before recording of the findings of this evaluation. Similarly the assessment should provide information for the evaluation of materials, methods, and a range of curriculum areas (Bitzer 1999).

6.2 NEW CHALLENGES

The main challenges impacting on assessment and evaluation practices in the new first-year curriculum at the School for Biological Sciences can be considered as the following:

- *Class size* : Since the implementation of new programmes of learning at the University of Stellenbosch in 2000 the interdisciplinary first-year curriculum in the Biological Sciences led to classes of up to 600 students. Traditional assessment systems were in many aspects simply too laborious to apply. Race (1999) warns against the use of especially continuous assessment processes that were designed when classes were much smaller. He calls for innovations in assessment, built on previous experience, and applied incrementally.

- *Introduction of new disciplines into the first-year curriculum*: Before the introduction of new programmes of learning (i.e. until 1999) the disciplines of Biochemistry, Genetics, Microbiology and Statistics were introduced to students only in their second year of study. In the new curricula the module Biology provided the opportunity for these disciplines to be introduced at the first-year level, but with very limited contact sessions with the students (only four to eleven lectures were allowed per department). The challenge was to compile the essence of each discipline into coherent lectures at a level different from what was previously the case. Students had limited and varying background to both Biology and Science. Assessment at an early stage would serve no other purpose but to determine the students' background knowledge – while too much assessment with such limited contact sessions, would be simply superfluous.

- *Practical course running congruently with the theoretical course, but not structured as well, and fraught with obstacles and problems* : During the first year of implementation (in 2000) the facilitators of the different sections of the course simply could not foresee a way of facilitating "wet practicals" for such large groups of students in the laboratories initially designed for Botany and Zoology, and without the necessary hardware required for the newly introduced disciplines. Therefore only Cytology (Cell Biology) and Microbiology provided practical classes, while a few videos were shown and discussed in the other lab sessions. It needs no explanation that this can hardly be the desired introduction to biology at university level...

6.3 PRACTICAL EXAMPLE

6.3.1 The Scenario

Globally assessment practices are being put under the magnifying glass, and critically evaluated. At the University of Stellenbosch the new programmes of learning that were implemented in 2000 provided unforeseen challenges to traditional assessment methods. Especially in the first-year curriculum in the

Biological Sciences, where classes are facilitated for up to 600 students, all traditional practices had to be reevaluated.

The biggest challenge was provided by the facilitation of a practical course in Biology 124, a module that involves facilitation by six different departments (Botany, Zoology, Genetics, Microbiology, Biochemistry and Nature Conservation). The practical sessions had to be facilitated synchronously with the theoretical lectures to enhance understanding of the theory.

From the start the practical programme was met with apprehension. Firstly the disciplines of Genetics, Microbiology, Biochemistry and Statistics have not in the past been introduced to first-year students. Now the lecture content which previously had been facilitated to second-year students only, had to be diminished without losing its content, to be introduced to novices in the biological sciences. Moreover, the contact sessions for each discipline varied as follows:

Cytology	4 lectures	2 practicals
Biochemistry	11 lectures	2 practicals
Microbiology	10 lectures	2 practicals
Genetics	4 lectures	1 practical
Evolution	4 lectures	1 practical
Statistics/How do we do Biology?	8 lectures	2 practicals

Table 1 : Number of contact sessions in different sections of Biology 124.

With this as the only background the students would have to perform practical laboratory work. To devise meaningful experimental procedures that would enhance the students' limited background at that point in time was already a challenge. To do so in laboratories neither designed nor equipped for "wet practicals" would provide an even bigger challenge. The final quest would then be to facilitate these practical sessions to almost 600 students in three different sessions every week (Tuesday mornings and afternoons, and Friday afternoons). As three first-year laboratories are available, each with working space for 70 students, every session consisted of three groups of students, each group assigned to a different laboratory. The demands on person-power ("lecture power") were rising even more, especially in cases where only one or two lecturers from a department were facilitating their discipline's section of the module to the first-year students.

When finally they were confronted with the prospect to assess the practicals, either on a regular weekly or fortnightly basis, or as a single practical examination, it ultimately provided the final straw that almost broke the proverbial camel's back. Inquiry about the preparedness of every lecturer involved in the practical programme to assess his/her section of the module, gave the following results:

Cytology	Yes	Microbiology	No
Biochemistry	Yes	Genetics	No
Statistics	Yes	Evolution	No

Table 2 : Need for assessment in different sections of Biology 124

The main arguments opposing assessment were the following:

- Only one practical session is facilitated in some sections, and the limited time does not allow the introduction to the practical subject, as well as a "test" on what has been carried out.
- The practical session is planned as a "fun practical" to stimulate students' interest in the subject, and not to evaluate what they have learnt.
- It simply takes too much time to mark 600 tests after every practical session.
- It is not possible to compile three different and fair tests for the three practical sessions with the limited time and person-power available – a single test would give an uneven advantage to both the Tuesday afternoon and especially the Friday afternoon groups.
- Student assistants were limited in some departments (Biochemistry, Genetics, Microbiology and Zoology), and a single lecturer cannot assess the practical competency in a group of 72 students in one laboratory.

6.3.2 The Event

After much debate it was decided that those lecturers who could manage to assess the students' laboratory work, and give their practicals a mark, would do so. This mark could or could not be used to influence the students' test or examination mark. In practice it worked as follows:

- In Cytology (Cell Biology) the students were given two short tests to write before the practical session started. A third test was added on the content of a video concerning Cell Structure and Function, that was shown during an extra unoccupied week. All tests were marked by the lecturers facilitating the practicals (three in total), plus the student assistants. The papers were also used as an attendance list, as no "role call" was taken. No evaluation of the students' practical skills/laboratory expertise was attempted. Ample student assistants were available (20 students per assistant). Students were allowed to work in pairs, but assessment was individual.
- In Biochemistry the first practical session was used as a Tutorial to enhance the students' problem solving skills. Complex chemical formulae and mathematical functions were introduced during the session, and assessed in a very "unfair" test (according to the students). A major problem was that only one lecturer and no assistants was available, no interaction between students and lecturer occurred in the tutorial, and the problems used for assessment in the tutorial were completely new to many of them. Resultantly many of them scored zero for the test.

  In the second practical a simplified version of a "real" biochemical experiment had to be carried out in pairs, but assessment was done individually. A short written report had to be handed in at the end of the practical session. Two assistants were available for the laboratory session, and a third one was responsible for marking the reports.

  This could have worked very well. However, the first problem that arose was that the responsible lecturer decided only after the reports had been handed in how points would be assigned to the different tasks and answers.

Students from the three laboratories, receiving instructions by three different lecturers or assistants, therefore emphasized different aspects of the practical results in their various reports – the group that was facilitated by the lecturer responsible for drawing up the experimental instructions and questions, therefore had an obvious advantage. Naturally this called for protest and annoyance under the students.

The second problem arose with the assistant responsible for marking the assignments. The specific person had no experience in evaluating papers, and simply gave a mark according to the final answer to every problem. He furthermore wrote degrading personal remarks /comments on the evaluation sheets – totally unasked for in a first-year (or any year) class.

- In Microbiology three lecturers, one of whom was the head of the department, were facilitators of the first-year practical sessions. They strongly felt that with the students' limited background to Microbiology, the laboratory sessions should be "fun practicals" . The students would have ample opportunity during their second and third years to be exposed to more formal practical sessions. Being a "fun practical" in the first place implied that no assessment of any kind was carried out.

- In Zoology one lecturer facilitated the practical session in the lecture hall. A tutorial was handed out, and completed with the aid of the lecturer. No assessment was carried out. Little interaction occurred between lecturer and students. One assistant was available to help the students complete the tasks.

- In the section *How do we do Biology?"* one lecturer, one post-doctoral fellow and a PhD student facilitated the practical sessions after an initial introduction to the whole group of students in the lecture hall. At least three postgraduate students were available as assistants in every laboratory. Practical work was carried out in groups, and individual reports had to be handed in at the end of every practical session. Resultantly the practicals were very long – up to 4 hours in some cases. This led to complaints from the students. A home assignment was also given, to be handed in at the end of the last practical. This assignment, as well as the reports, were marked by the student assistants. The students were informed that these marks would only be applied in a positive way, i.e. to raise their marks when needed.

It is therefore obvious that the practicals of the various sections of the module Biology 124 were both facilitated and assessed in various ways. The most relaxed ones being the "fun practicals" of Microbiology and the Genetics tutorial. However, despite the tests written before every Cytology practical the students found the hands-on experience in the laboratories, as well as the congruence between theoretical lectures and practical content most rewarding. In fact, they asked for an additional Cytology lab session when they had an open week to which no practical had been assigned, and they were given a choice on how to occupy that session.

6.3.3 The experience

In the penultimate week of classes the students were asked to complete a questionnaire concerning the practical course in Biology 124 (see Addendum 1: Section B). As the questionnaire was completed during a normal practical session a return rate of 73% was obtained.

In the questionnaire students reflected on the following:
(**Question 1)** Did they enjoy the practical sessions?
(Question 2) Did they find the student assistants efficient in helping them?
(Question 3) Would they like to have student assistants at every practical session?
(Question 5) Did they prefer to do a practical in the lab or a tutorial in the lecture hall?
(Question 6) Did they want to be evaluated and assessed for practical lab skills?
(Question 7) Did they want their practical mark to be used in any final assessment?
(Question 8) Did the practical course meet their expectations?

The individual sections of the module were analyzed in a separate table (**Question 4**) where students indicated in which disciplines

- They had enough theoretical background to perform the practical work.
- The practical work helped them to understand the theoretical work better.
- The practical sessions only increased the volume of work they had to study.
- They did not understand the work done in the practical sessions.
- They wanted to do more practical work.
- They wanted to do less practical work.

Students' response showed that they generally enjoyed the practical classes (Figure 1). Although enjoyment is not the motivation for having or adapting practical classes, it can have an influence on the amount of learning that takes place (Entwistle 1998, 2000). Their feedback also revealed that some of the problems with the course could directly influence their enjoyment because it provided irritation and insecurity. Many students remarked on the lack of information before the practicals, revealing a need to come prepared to the practicals. A structured laboratory guide with the semester's practicals set out in it could provide an easy solution to that request (see Discussion and Recommendations).

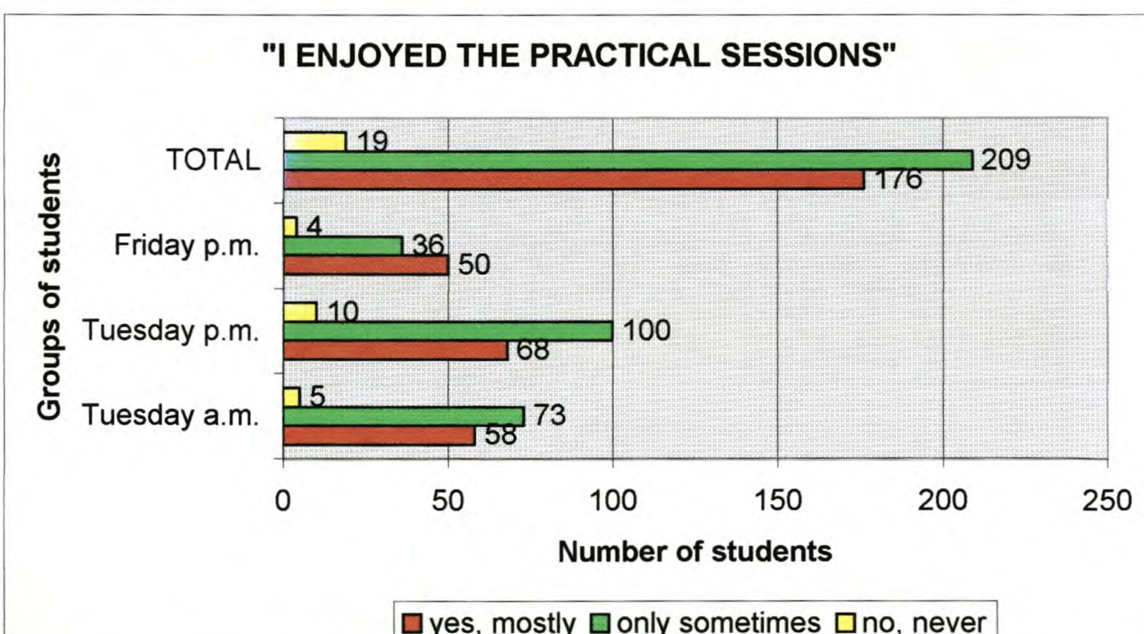

Figure 1 : **Students' feedback on their enjoyment of the practical classes**

Questions involving the need for and efficiency of student assistants (mostly honours students helping with the practicals either out of an interest in teaching in the discipline, or due to a need for an extra income) revealed that they were mostly efficient (Figure 2), although many students remarked that the assistants could have been better prepared for their questions. However, Hilosky, Sutman and Schmukler (1998) mentions how self-motivated learning can be better accomplished when laboratory overseers (and in this case assistants) do not serve as the verbal source of procedural help. Students in laboratory settings should learn to develop self-reliance and reliance on one another as a team. Our responsibility is to guide the assistants on the way, and indicate the level of assistance and involvement with the students' practical work. The need for assistance is clear (Figure 3), and in this module where some departments did, and others did not provide assistants, the students were made even more aware of the role and usefulness of lab assistants.

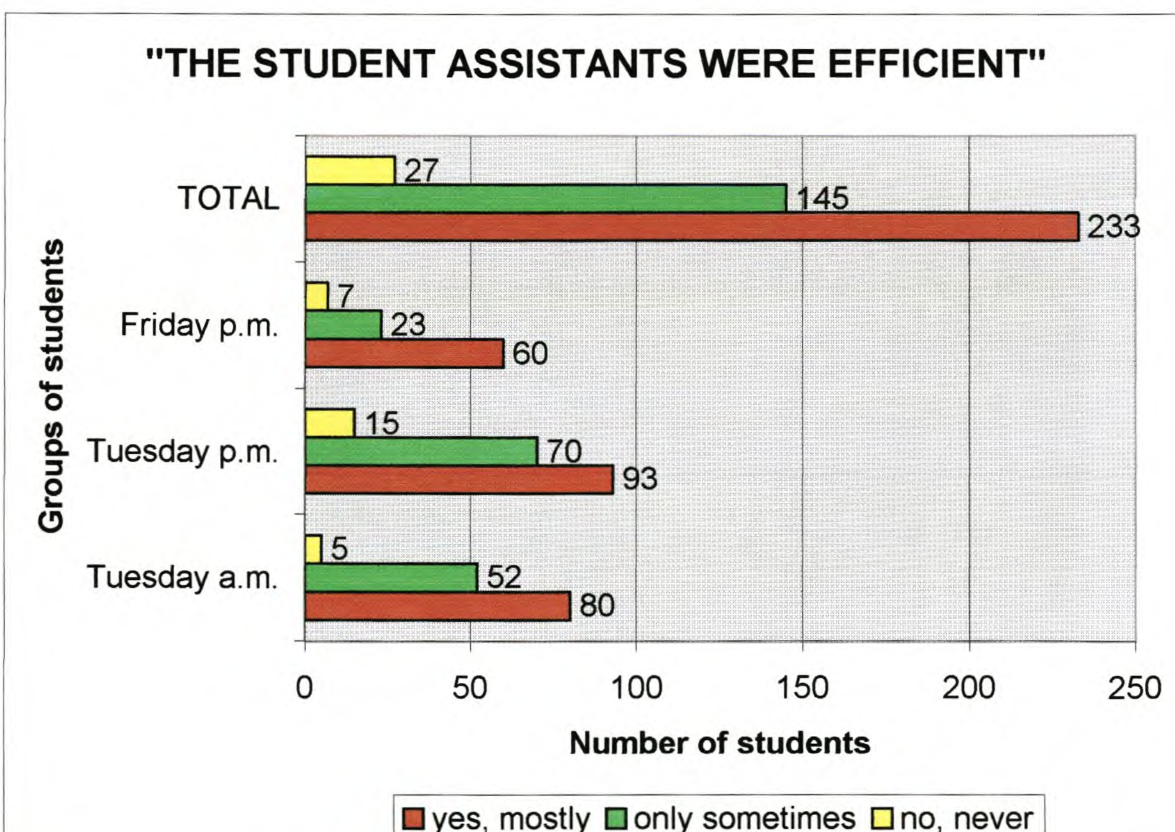

Figure 2 : **Students' feedback on the efficiency of student assistants**

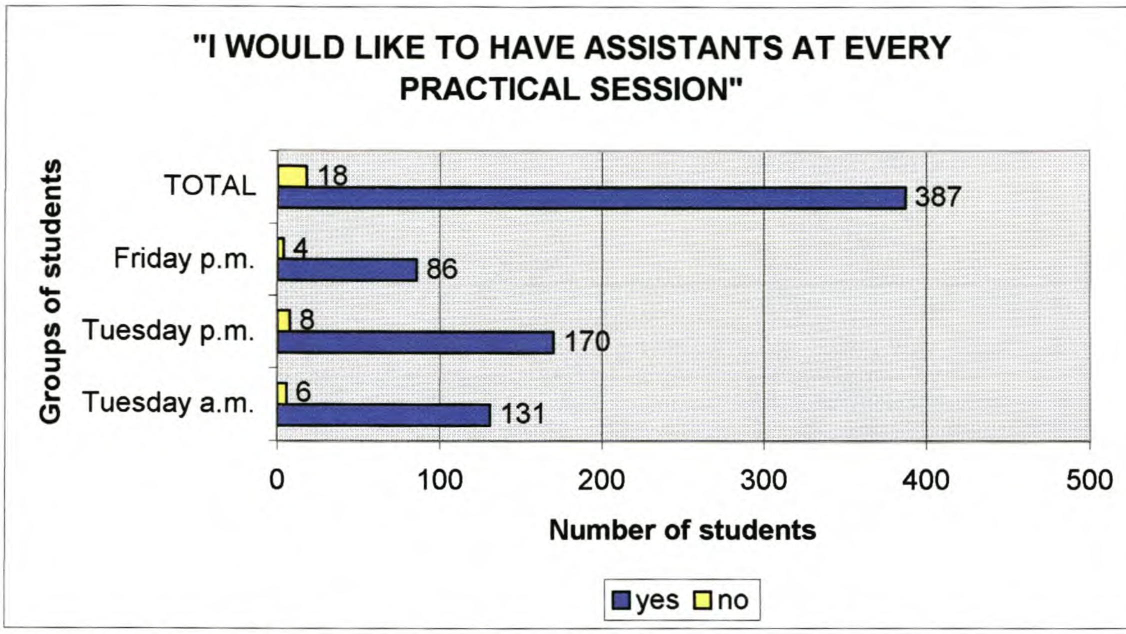

Figure 3 : **Students' need for assistance with practical sessions**

Inquiry into which type of practical sessions the students preferred – a "wet practical" in the lab or a tutorial working on problems more theoretical of nature, the vast majority preferred the laboratory work (Figure 4). This simply amplifies the urgent need for adapting and even transforming the practical part of first-year biology to improve its application as a tool for promoting deeper learning through hands-on experience (Lord 1998, 2001).

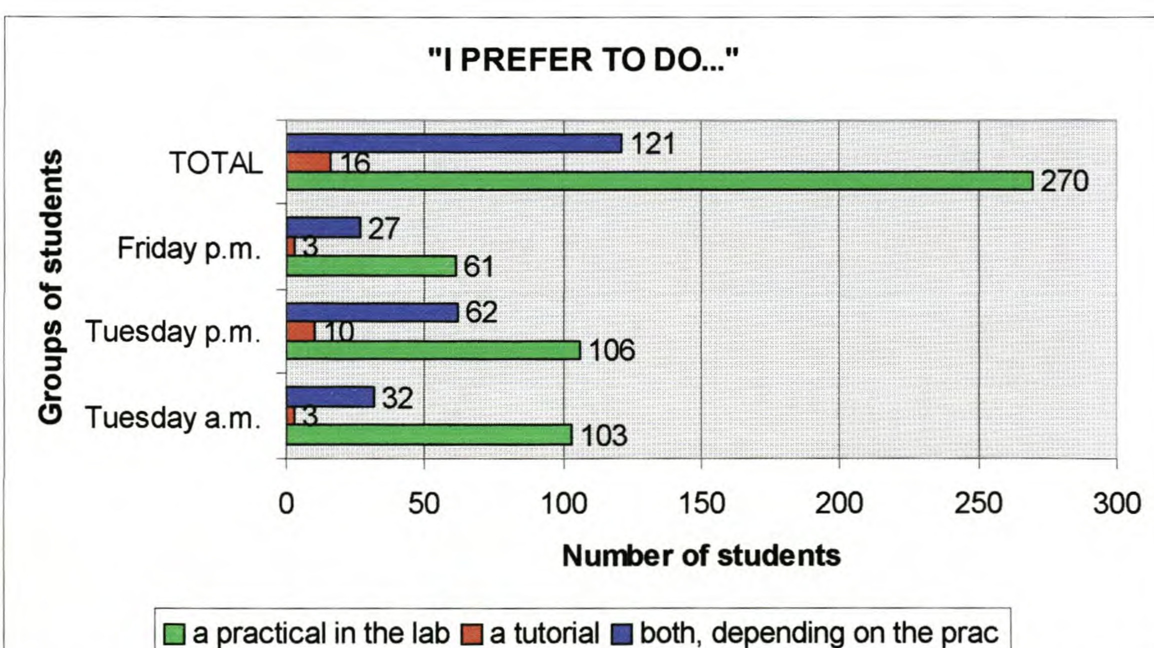

Figure 4 : **Students' preference for practical versus theoretical work**

The students' feedback on the assessment of their practical work revealed some interesting aspects (Figures 5 & 6). It came as a surprise that the students actually preferred assessment of their practical work, but that they did not want this mark to be used as an exact percentage of their final examination mark. This indicates that the students prefer the assessment of their practical work not to score marks for the exams, but to give an indication of their level of understanding, thereby promoting active learning. This negates the general feeling under lecturers in this module that students will be unwilling to attend practicals and exert themselves with assignments and lab books if the marks were not "used" in some way.

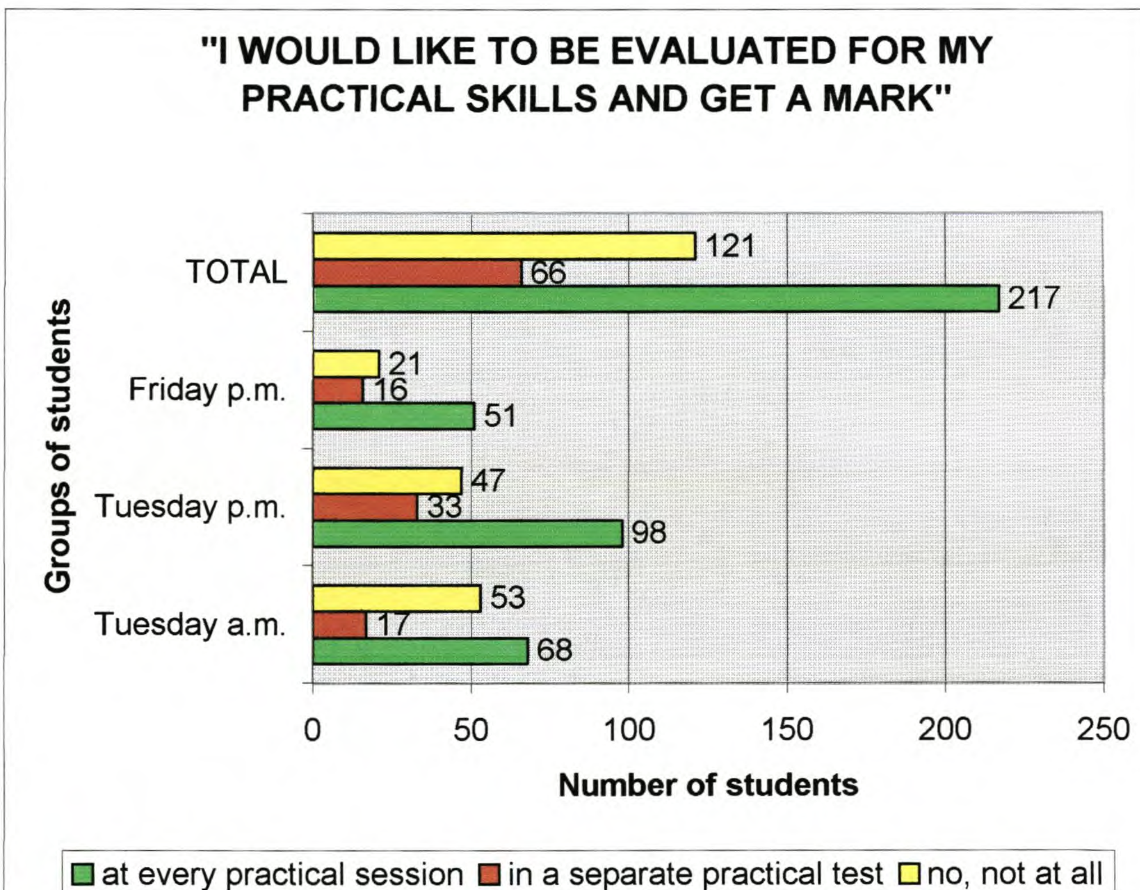

Figure 5 : **Students' need for evaluation of their practical work**

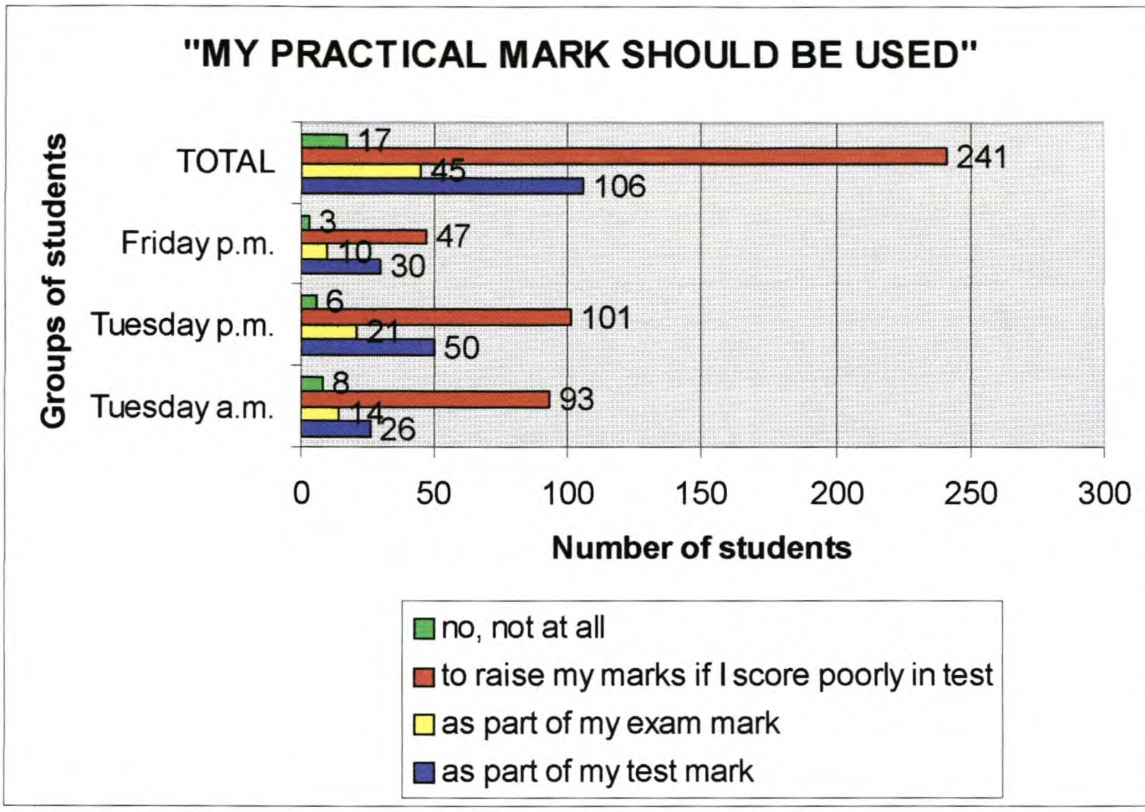

Figure 6 : **Students' opinion on the application of their practical mark in their general evaluation.**

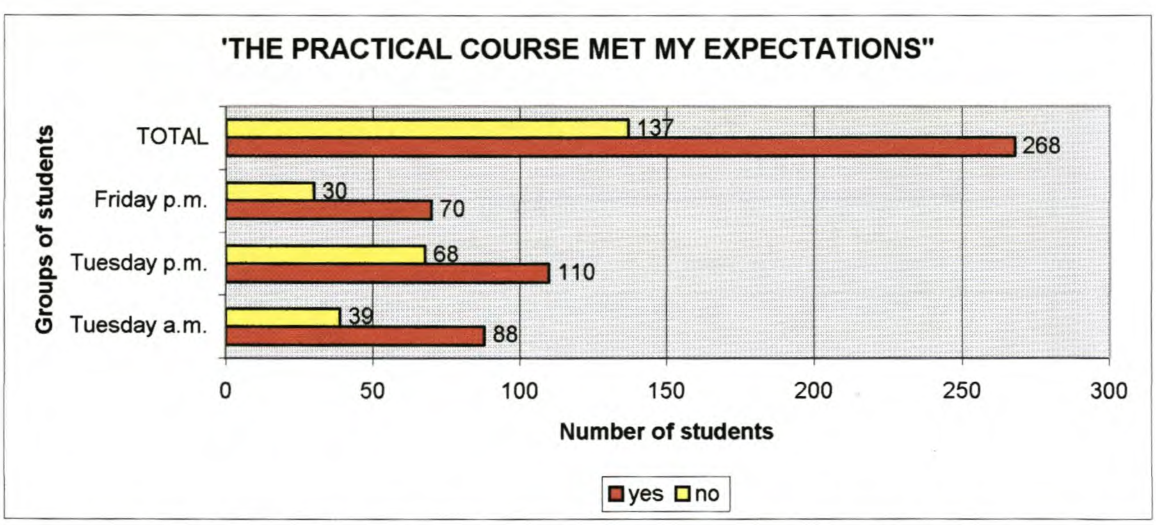

Figure 7 : **Students' feedback on their general satisfaction with the practical course**.

In their general evaluation of the practical sessions twice as many students were satisfied with the course as opposed to those who felt that the practical course did not meet their expectations (Figure 7).

6.4 DISCUSSION AND RECOMMENDATIONS

As lasting learning is promoted when students are actively involved in thinking about what is being heard, seen or done (Lord 1998, 2001), the practical part of Biology 124 should provide an ideal milieu in which to enhance the theoretical lectures, thereby facilitating deeper learning. However, the amount of apprehension with which the practicals were met in the novel environment provided by the new programmes of learning proved to be the greatest obstacle to overcome. This can have serious consequences, as the enthusiasm and empathy of the lecturer powerfully affects the students' interest, motivation and engagement with new ideas (Entwistle 2000). The biggest challenge would thereby not lie in the practical facilitation of the laboratory sessions, but in inspiring the contenders to be innovative, and to grab the opportunity to utilize the laboratory sessions as practical extensions of the theory. They would move mostly into uncharted territory, as the traditional disciplines of "botany" and "zoology" on first-year level are globally being replaced by "biology" as an interdisciplinary subject. However, a valuable contribution could be made to knowledge on:

A what type of biology practicals "worked" on first-year level;

B what type of "wet practicals" could be carried out in a "dry laboratory" with limited facilities;

C how best to facilitate and assess practicals to large groups of students;

D what type of technology could be applied to ease facilitation and assessment of practicals;

E how assessment could be carried out in such a large group of students;

F how assessment could be applied to enhance the learning process.

My recommendations, based on what I experienced in my involvement with the course, as well as on the students' feedback, reflect on the above-mentioned points.

Points **A** and **B** fall outside the scope of this study, and it is sufficient to say that a variety of practicals can be carried out in these laboratories, providing the facilitators are willing to adapt some experiments, and be innovative with the use of the limited glassware, complete lack of gas burners, lack of wash basins (only one basin per lab bench, i.e. per 9 students) and limited experience of the students. Some work will have to be done on a rotation basis, some solutions prepared ahead of time by the technical assistants, and some bigger experiments divided between different groups of students – even different lab benches – and the results combined eventually to obtain a full picture.

This ties up with point **C**, i.e. the different techniques that can innovatively be applied to facilitate and enhance practicals to a large group of students. One of the shortcomings of the course, which was pointed out by many students in the questionnaire (Question 9, see Addendum 1B), when asked what they would like to see improved in the practical course, was the lack of a "laboratory guide". Presently students receive a copy of the instructions for the laboratory session at the start of every practical. Compilation of a practical guide by the various departments involved in the module would give structure to the practical course, and give the students the opportunity to come prepared to the practical sessions. Many students indicated the need to prepare themselves, either by revision of their theoretical lectures, or by searching on the internet for information on the subject to be experimented with. This can be of great value especially where practical sessions do not always run congruently with the theoretical sessions, and when the content of the practical does not elaborate on the theoretical work covered in the lecture hall. I found this request from the first-year students (to enable them to come prepared to practicals) very encouraging.

It can be concluded that a lack of *structure* is a common shortcoming in this laboratory course. Interestingly Gibbs (1992) found that students found large classes overwhelming but manageable as long as there is a *structure* to the module detailed in a workbook. Providing general structure in the laboratory set-up will also improve the efficiency of time-management in the laboratory. At the moment students can do a session in any of the three labs, using any preferred lab space. This greatly restricts the feasibility of any group work, especially if the experiments run over more than one lab session. Great confusion, a waste of precious time and poor reports resulted from a lack of this very elementary principle: let every student be assigned to a specific lab space (of choice if desired). This will also ensure that absentees can be distinguished at a glance. The current practice of handing in reports, or writing tests solely as a means of taking role call, is in fact absurd.

The availability of a practical guide (or so-called "lab book" / "lab file") could also be exploited in the assessment, which only three of the six departments involved was willing to do. From students can be expected to add their experimental results, or answer sheets from every practical, to the lab book (providing space to paste it in), or ideally to do so in the form of a ledger to which extra sheets can be added easily. This lab book can then be assessed once or twice during the semester, and feedback provided with marks also scored for layout of the file, innovation in compilation, style of writing, and even neatness of the report. More formative assessment will be carried out this way. Short essays or reports on literature searches can be included in such a file, giving an indication of the depth of learning that has taken place. This will in fact contribute to portfolio assessment in the module.

D. This aspect provides enough scope for an additional paper, as technology in the sciences is advancing at such a rapid pace, that existence of technology is not so much a problem as experience and confidence to apply it in a lab setting. Thompson and Trotter (1998) report on a successful restructuring of their module with extensive use of Computer Aided Learning (CAL), while More & Ralph (1992) report on the increase in knowledge in biology students taught with computers, compared to those in traditional laboratories. Apart from the use of computers digital equipment is becoming more and more available to enhance teaching and learning, and even make it more fun. According to Watts (1991) it is always easier to relate to someone having fun, and to him science *is* fun – lecturers should reveal their passion for science in the laboratory, and utilize digital equipment to effectively do so to a large group of students.

Francis (2000) regard the Internet as a tremendous resource for science educators, providing experimental data, software, multimedia technologies and communication links with libraries and scientists. Slish (2000) discuss the application of GIF (Graphics Interchange Format) animation to facilitate understanding of biological concepts, while Sanger *et al.* (2001) apply computer animations successfully to promote the development of accurate concepts of processes in nature. Mills *et al.* (2001) describe the use of a digital camera system to document observations in a Microbiology Laboratory Class, thereby greatly enhancing the students' experience of practical microscopy. Simon (2001) and McLaughlin (2001) and Gepner (2001) all describe the transformation of their lectures and practical sessions with the application of CD-ROMs, Web-based active learning modules and Dynamic HTML in the Biology laboratory.

Technology-based assessment is also becoming a common phenomenon in Higher Education. Many existing web-based assessment systems, such as Blackboard, Web-CT and TopClass, support multiple choice testing. Lister and Jerram (2001) report on the successful implementation of multiple choice exams using XML to randomly generate subsets of questions for regular small assessment tasks. This can greatly simplify assessment of large classes - as is the case in the first-year curriculum at the University of Stellenbosch. Furthermore, it provides students with the opportunity to be examined repeatedly from a pool of questions. This is in accordance with Bigg's view (1999a) that student learning can be structured via assessment tasks.

Integration of a web-based learning (WBL) system into teaching and learning furthermore normally indicate a shift from a teacher centred to a student centred practice. Housego and Freeman (2000) report on a series of case studies where application of a WBL system, with alignment of assessment tasks with course objectives, greatly encouraged students to take a deep approach to learning. The system also allows for formative feedback and discussion. A further advantage is that evaluation is deeply embedded in the process, with semester surveys and focus groups for feedback on the system. However, the initial positive reaction of students to a technology supported learning tool may simply be the inspiration provided by an enthusiastic innovator (Housego & Freeman 2000).

However, the disadvantages provided by failing hardware, the availability of technological facilities and the students' familiarity with the use of technology must be taken into consideration. Windelspecht (2001) cautions biology lecturers to break the dual learning curve that can develop with implementation of a technology driven course.

It is essential to be aware of the obstacles as well as the opportunities provided by technological innovation in teaching, learning and assessment. Freeman and Capper (2001) categorize the obstacles to technology-supported learning and assessment according to typical stakeholder group, i.e. the Students, the Academics and the Institutions. It is essential to be diligent in evaluating outcomes. Such evaluation should go beyond a focus on technologies to the essential goal of improving student learning rather than simply student reactions (Laurillard 1993). Freeman and Capper (2001) furthermore strongly advise academics not to be hypocritical in placing stringent benchmarks on a technology-supported teaching or learning activity when current activities are not evaluated in terms of their learning outcomes.

E. Various web-based tools are available for assessment of large groups, as outlined above. However, this is not the only option available. Innovative use of the available personpower in the form of laboratory assistants can help facilitate assessment on a continuous basis. Group-work for carrying out experiments build skills like teamwork, communication and adaptability, and different groups can be allowed to assess each other's work, with the lab assistants advising and the lab overseer or coordinator directing the process.

Techniques like peer appraisal of practical work (Mockford & Denton 1998) and oral assessment (Joughin 1999) can also be applied fruitfully, especially in the milieu provided by a practical laboratory setting. When designed and applied properly, oral assessment can test a variety of skills and qualities, like knowledge and understanding, applied problem solving ability, interpersonal competence and personal qualities. Mockford and Denton (1998) have found that peer appraisal of practical work limits the occurrence of strategic learning, while also being a catalyst in compressing the period of change in a new educational context. However, peer appraisal should be applied with caution, and research needs to be extended on this aspect, as indicated by the findings of Norton and Brunas-Wagstaff (2000).

These authors found that group-assessment, particularly peer-assessment, was regarded as "less fair than exams". This probably reflects the students' underestimation of their fellow students' ability, as well as their ability to judge (Norton, Brunas-Wagstaff & Lockley 1999).

Students appreciate flexibility, and a choice of assessment activities can have a marked positive effect on motivation (Housego and Freeman 2000). With the variety of departments involved in the facilitation of interdisciplinary first-year biology, it is advisable to experiment innovatively with standard and novel assessment techniques until workable practices are found.

It is evident that the students want to be assessed on each session's practical work. This can be done by supplying a memorandum either on the bulletin board, or on the intranet using Web-CT. Preferably students should be assessed while doing the experiments, and not leave the laboratory until the practical work has been carried out satisfactorily. This will only be possible with ample provision of lab assistants, which is **not** unattainable in Biology 124. To my opinion even motivated and instructed third-year students can assist first-year students in a laboratory setting. However, they should be properly briefed before each lab session, and receive additional instruction on assessment practices.

F. The quest to apply assessment techniques that will truly enhance the learning process is easier said than done. It has been shown that students who are not fully engaged with the learning tasks, or who perceive assessment to be artificial and meaningless, tend to adopt strategic methods of studying (Scouller 1998), or adopt an approach described as "technification" of learning (Marton & Saljo 1997). This means adopting an "artificial deep approach" to learning, perceived to be rewarded by lecturers, rather than genuinely interacting with and learning from the task at hand.

The aim therefore is to apply assessment techniques that will fully engage the students in their tasks, while simultaneously being sincere and candid, as well as meaningful and consistent. If we want to move away from a tradition of spoon-fed students to a milieu of critical thinkers, we shall also have to bear the consequences of being scrutinized by those inquiring minds.

'Assessment-for-learning implies feedback' (Lister & Jerram 2001). Feedback on student performance, as well as feedback on course evaluation can be raised here. This implies more time and better techniques to be devised for feedback. Again information technology (IT) can be utilized with facilities like electronic mail, Web-CT, chat rooms and web conferencing.

Whether the assessment should be in the form of a mark which is used in calculation of their final marks, is debatable. This should be determined by the objectives and desired outcomes of the module, and specified as such. If experimental dexterity and laboratory skills are desired, a certain percentage of the final mark should be allocated to the practical section of the module. If more emphasis should be placed on the practical skills of the students, the practical section should probably be re-engineered to form a separate practical module, which emphasizes additional skills like research project planning, experimental layout, laboratory safety, and project writing. Such a module will not necessarily run congruently with the theoretical lectures, and can be facilitated by staff other than the normal lecturers. In such case the practical module should be designed with great care in order not to restrict the benefits of the traditional "If I do, I understand" system - which implied "I understand the theoretical lectures better". Simply increasing the workload of the students with the introduction of an additional laboratory module will not promote deeper learning of biology.

Assessment should never dominate an activity or programme (Boud 1990; Mockford & Denton, 1998; and others), even when it is innovatively made integral to student learning (Nortin & Brunas-Wagstaff 2000). According to Boud (1990) the paradox is that assessment can often do the opposite of its intended aim: it can encourage strategic learning and competitiveness, and sometimes it even encourages students to focus on those things that are assessed at the expense of those things that are not.

According to Lauvas, Havnes and Raaheim (2000) it is not possible to design assessment systems where all concerns are met equally well each time students are assessed. Priority has to be given to some concerns at the sacrifice of others, and the system has to be developed continuously. A variety of assessment methods should be applied, while the risk of over-assessment is imminent. Furthermore, assessment systems should be characterized by manageability of assessment and record-keeping.

The most significant barrier to change is often the academic's own attitude towards current methods and concepts (Warren Piper 1994, Housego & Freeman 2000). Resistance to change is human, and persistence in spite of the well-documented inefficiency of current methods, is a common phenomenon. It was encouraging to hear facilitators of this module describe their attempts at changing the practical sessions to be more on par with 'real life situations' (Ward 2002).

6.5 CONCLUSIONS

In the module Biology 124 the practical sessions should be designed to promote learning, and assessment thereof applied to further attainment of that goal. It has been shown that across the sciences, inquiry-based laboratory experiences did result in significantly improved cognitive and non-cognitive content learning (Hilosky *et al.* 1998).

My recommendations for adaptation of the module Biology 124 not only to promote deeper learning, but also to enhance enthusiasm for biology, while keeping the manageability of a large class in mind, can be summarized in two main points, i.e. **structure** and **assessment**.

By giving more structure to the course in all aspects from the general laboratory setup (space assignment, laboratory guides, work books and lab assistants) will not only enhance practicability of various tasks, assessment techniques and facilitation, but also increase the credibility and general profile of the practical sessions. However, the first structural aspect currently lacking in the module is the specification of learning outcomes and objectives for the practical part of Biology

124. Only when definite outcomes have been specified can we practically and innovatively design techniques and systems for obtaining those outcomes.

Application of various assessment methods, including those utilizing the available IT infrastructure, should be continuous, but not predominant. If mainly peer- and self-assessment techniques are used, great caution should be applied in the utilization of these marks in the students' final evaluation. The myth that students will only be dedicated towards assessment if all marks are used in their final evaluation also belongs to the past.

Transformation of practical biology teaching is imperative. Reform in assessment formats and techniques may indeed be one of the pivotal pieces around which attainment of our outcomes of learning turns.

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CHAPTER 7

Integration

Transformation in biology teaching is inevitable. Motivational forces initiating and driving this change come from various directions and disciplines. In many cases such changes are even described as a 'paradigm shift' or a 'revolution'.

A major catalyst in the transformation in biology teaching is the transformation in biology content. This is partly caused by the exponential advance in general research and information technology, as well as the paradigm shift to the molecular sciences and biotechnology. To be marketable the content of curricula have to be relevant. Attainment of relevance was made possible through the introduction of interdisciplinary programmes of learning. Integration of information from various interrelated disciplines would lead to the attainment of relevant and marketable knowledge. Naturally this led to drastically altered curricula, departments and even faculties. The establishment of 'Schools for Biological Sciences' is a global phenomenon reflecting this new cohesion between especially the fields of Biochemistry, Microbiology and Genetics – as well as Plant and Wine Biotechnology.

New programmes of learning resulted in a changed student composition, and also a rapid increase in class size. At the University of Stellenbosch the merging of the Faculties of Agriculture and Forestry furthermore contributed to this growth in student numbers in various traditional lectures. Classes that previously consisted of 30 students now contain more than 200 learners – but with the same number of lecturers to facilitate the specific lectures. This naturally led to a greater student:lecturer ratio, with the subsequent loss of valuable personal interaction. A plethora of practical problems emerged. This varied from the size of the lecture hall, to the infrastructure available in the laboratories, to the practicability of laboratory curricula.

In South Africa all these academic changes were attended with a major shift in the political scenario. Coinciding with political transformation new challenges were laid before the doors of Institutes of Higher Education. Resultantly, when yet another transformation – from an Instruction Paradigm to a Learning Paradigm - was proposed, lecturers were in many cases apathetic or even antagonistic towards this paradigm shift.

From the start it was evident that no single or simple solution would be found to solve the complexity, magnitude and variety of problems that arose with implementation of the new programmes of learning. Therefore, in this study, various ways were explored to enhance the teaching of first-year biology at the University of Stellenbosch, while simultaneously dealing with various practical and fundamental issues in lecturing.

An interdisciplinary approach was therefore also followed in devising a workable solution to the practical problems. Technology, and specifically information technology proved to be invaluable, especially where large classes were concerned. However, while information technology provides a powerful tool with which to enhance teaching, it is not a solution *per se*. It does, however, provide tremendous scope and capabilities to enhance facilitation in large groups, in laboratory sessions, and of market-oriented issues. It should be emphasized that provision of IT tools and facilities do not necessarily imply their application and effect. Pilot studies should be carried out to determine the specific needs and possible impact on quality of teaching before a specific IT tool is applied.

In many cases it became clear that enhancement of biology teaching can be accomplished by innovation and inspiration. This is easier said than done. Transformation in education is a slow and laborious process, even exhausting at times. Without due compensation for teaching activities, inspiration can easily be compromised. This will not easily be accomplished. While compensation for research activities is based on number and impact of research publications, the level of learning attained in students is not an easily quantifiable entity.

There is a great need for transformation in the way facilitators of quality learning are regarded and esteemed. In many cases they are the ones inspiring future great minds to follow a path that might ultimately lead to Stockholm to join a dynasty of Nobelists.

It is often feared that the soul of higher education might be lost in today's transformation. Loss of the soul of science might also be apprehended in today's research driven university system. It is up to us science educators to distill the original essence of this soul. Change has always been a part of higher education – only this time the rate of change increases exponentially. This implies that, as in Darwinian evolution, our changes should be useful adaptations, enabling us to cope with a transformation in science. As academics we must not lose perspective and regard all change as a threat to survival. Careful pruning is necessary for growth, and getting rid of the dead wood of unmotivated practices may be the process needed to obtain future excellence.

Enhancement of quality in biology teaching therefore necessitates an adaptation or even transformation of old *modi operandi.* This implies a bold and scrutinizing inquiry into our systems and practices, as well as the exploitation of available resources. We have a unique opportunity to remake biology teaching into a stimulating and thought-provoking experience, while inspiring our students with our vision and philosophy.

The key to our success lies in a willingness to act together as an academic community with shared values and a commitment to science in general. We can take the best of our current practices, use advanced technology, integrate, manage and apply to enhance the quality of our teaching – and to take part in the rebirth of the soul of science in higher education.

We hold this soul in our hearts and in our hands.

ADDENDUM 1

Questionnaire for Biology 124 students

QUESTIONNAIRE FOR BIOLOGY 124 STUDENTS

A. EVALUATION OF CD-ROM SUPPLIED WITH TEXTBOOK *BIOLOGY* (RAVEN & JOHNSON)

In every case mark only the ONE answer which most accurately describes your situation, unless otherwise requested. Information will be treated as confidential and anonymous, and will in no way affect your marks.

1. Gender

☐ Male ☐ Female

2. Test mark...............%

3. I follow the B.Sc. programme in

☐ Molecular and Cellular Biology
☐ Biotechnology
☐ Ecology and Biodiversity
☐ Human and Life Sciences
☐ Physical and Earth Sciences
☐ B.Sc. Agric
☐ B.Sc. Forestry
☐ Other (specify)..................................

4. I passed the following subjects for my matriculation certificate

(mark all appropriate boxes and indicate the symbol on your matriculation certificate)

☐ Biology..............................Symbol.........
☐ Chemistry/Physics...............Symbol.........
☐ Mathematics........................Symbol.........

5. I use the CD-ROM supplied with the textbook *BIOLOGY (Raven & Johnson 1999)*

☐ Yes - If **Yes** skip question 6 ☐ No – if **No** leave out question 8

6. I do not use the *BIOLOGY* CD-ROM because

(mark all the appropriate boxes)

☐ I do not have a copy of the CD-ROM
☐ I do not have access to a computer
☐ I do not have access to a computer with a CD-drive
☐ I do not know how to use the CD-ROM
☐ I do not have the time
☐ I find it unnecessary
☐ Other (specify) ....

7. I use the *BIOLOGY* CD-ROM

☐ Only before tests/examinations
☐ More than once a week
☐ Less than once a week, but more than once a month
☐ Never
☐ Other (specify)..

8. For every statement mark the block which most accurately describes your opinion

	Definitely disagree	***Disagree to some extent***	***Agree to some extent***	***Definitely agree***
The CD-ROM summarizes the work well				
The CD-ROM makes the work more interesting				
The CD-ROM relates well to the class notes				
The CD-ROM only confuses me				
The CD-ROM only increases the volume of work				

Any other remarks on the CD-ROM..

....

....

9. I get information relevant to my studies on the internet

☐ Yes ☐ No

10. The university's website should be used to provide
(mark all the appropriate answers)

☐ An elaboration of the curriculum, i.e. a framework and details of the content of modules

☐ Memorandums of the tests

☐ Home assignments

☐ Short quizzes to test my knowledge

☐ Important information (e.g. dates, venues, results, etc.)

☐ Other (specify)...

11. I would like to communicate to the lecturer via e-mail

☐ Yes ☐ No

12. I have my own computer

☐ Yes ☐ No

13. I have access to a computer

☐ At my residence ☐ At a computer centre of the university

☐ Other (specify)...

15. Any remarks on the computer facilities and facilitation on campus

....

....

....

B. EVALUATION OF THE PRACTICAL COURSE IN BIOLOGY 124

In every case mark only the ONE answer that most accurately describes your opinion, unless otherwise requested. Information will be treated as confidential and anonymous, and will in no way affect your marks.

1. I enjoyed the practical sessions

- ☐ yes, mostly
- ☐ only sometimes
- ☐ no, never

2. The student assistants were efficient in helping me with experimental problems

- ☐ yes, mostly
- ☐ only sometimes
- ☐ no, never

3. I would like to have student assistants at every practical session

☐ yes ☐ no

4. Evaluate the different sections of the practical course, marking all the appropriate blocks

	Cytology	Biochem.	Microbiol.	Genetics	How we do Biology	**Any comment?**
I had enough theoretical background to perform the practical work						
The practical work helped me to understand the theoretical work better						
The practical sessions only increased the volume of work I had to study						
I did not understand the work done in the practical sessions						
I would like to do more practical work in these sections						
I would like to do less practical work in these sections						

5. I prefer to

- ☐ do a practical session in the laboratory
- ☐ do a tutorial
- ☐ do both, depending on the nature of the work
- ☐ other (specify)…………………………………………………..

6. I would like to be evaluated for my practical work and get a mark

- ☐ at every practical session
- ☐ no, not at all
- ☐ in a separate practical test

7.My practical mark should be used

- ☐ as part of my test mark (klaspunt)
- ☐ as part of my examination mark (Junie-eksamenpunt)
- ☐ only to raise my marks if I do not get 40% in my test
- ☐ no, not at all

8. The practical course met my expectations

- ☐ yes
- ☐ no

9. I would like to see the following improved in the practical course ……………………………………
………
………
………
………

C. FOCUS ON THE SECTION "*HOW DO WE DO BIOLOGY?*"

1. I found the content of the lectures

- ☐ interesting
- ☐ above my level of understanding
- ☐ did not interest me
- ☐ other (specify)……………………

2. I found the presentation (aanbieding) of the lectures

- ☐ stimulating
- ☐ boring
- ☐ other (specify)……………………………………

3. I had problems understanding the English

- ☐ yes
- ☐ no
- ☐ other (specify)……………………………………

4. The practical sessions related well to the theory

- ☐ yes
- ☐ no
- ☐ other (specify)……………………………………

5 The statistical work in the practical sessions were

- ☐ easy to grasp
- ☐ difficult, but interesting
- ☐ difficult, not interesting
- ☐ other (specify)…………………………………………………………………

6 Any remarks on specific aspects of the theoretical or practical part of "How do we do Biology?"

……
……
……
……

Thank you for taking the time and effort to complete the questionnaire.

Baie dankie vir jou tyd en moeite met die vraelys.

(dr.) Lydia-Marié Joubert School for Biological Sciences Skool vir Biologiese Wetenskappe

ADDENDUM 2

Correlation matrix of variables responded to in the Questionnaire.

	YES	NO	MALE	FEMALE	%	BIOLOGY	SCIENCE	B.Sc.Agric	B.Sc.Cons	B.Sc.Biol	Other	COPY ?	CD-DRIVE	HOW?	TIME?	NECESS?
CD-ROM YES	1															
CD-ROM NO	-1	1														
MALE	0.033247	-0.033247	1													
FEMALE	-0.033247	0.033247	-1	1												
%	-0.018439	0.018439	-0.151929	0.151929	1											
BIOLOGY StdX	-0.077454	0.077454	-0.188339	0.188339	0.121369	1										
SCIENCE StdX	-0.070896	0.070896	0.136603	-0.136603	0.023243	-0.046261	1									
B.Sc.Agric	0.001694	-0.001694	0.261136	-0.261136	-0.179591	-0.140077	0.047434	1								
B.Sc.Cons	0.043777	-0.043777	-0.254592	0.254592	0.043684	0.022018	-0.256626	-0.202991	1							
B.Sc.Biol	-0.011479	0.011479	-0.0606	0.0606	0.13577	0.14975	0.10091	-0.590707	-0.371836	1						
B.Sc Other	-0.026986	0.026986	0.012044	-0.012044	-0.001503	-0.065873	0.032124	-0.212818	-0.133964	-0.374835	1					
COPY ?	-0.399791	0.399791	-0.00825	0.00825	0.181309	-0.019272	0.018458	-0.023845	-0.030625	-0.011403	0.061999	1				
CD-DRIVE ?	-0.306922	0.306922	-0.017854	0.017854	-0.172099	0.027591	0.009741	0.0041321	0.0359936	0.044642	-0.089872	-0.365708	1			
HOW TO USE?	-0.131851	0.131851	0.016774	-0.016774	-0.160458	0.004373	-0.013358	0.0827797	-0.009552	-0.054538	-0.016038	-0.157105	-0.120611	1		
NO TIME?	-0.181224	0.181224	-0.019246	0.019246	0.027842	0.051322	0.063269	-0.076718	-0.029775	0.040517	0.067403	-0.215972	-0.16457	-0.071191	1	
NECESSARY?	-0.157651	0.157651	-0.004178	0.004178	0.079626	0.062086	0.0121	0.0491764	-0.035954	-0.03019	0.01632	-0.187846	-0.144211	-0.061952	-0.085123	1
FOR TESTS	0.711866	-0.711866	0.065237	-0.065237	0.01826	-0.039773	-0.077183	-0.071398	0.0731011	0.018709	-0.005657	-0.284597	-0.218488	-0.09386	-0.128981	-0.112226
1-7x/WEEK	0.172208	-0.172208	0.028076	-0.028076	0.053578	0.034332	-0.05987	0.0595064	-0.035657	-0.003934	-0.037383	-0.068847	-0.052855	-0.022706	-0.031196	-0.027149
1x/WEEK-MONTH	0.504982	-0.504982	-0.031622	0.031622	-0.061877	-0.04785	0.022433	0.04677	-0.018042	-0.029832	0.001644	-0.201887	-0.15499	-0.066583	-0.091487	-0.079611
NOW & THEN	0.24476	-0.24476	0.003084	-0.003084	-0.026383	-0.066385	-0.021116	0.0845766	0.0052332	-0.041063	-0.053133	-0.097853	-0.075122	-0.032272	-0.044339	-0.038587
SUMMAR.WORK	0.947596	-0.947596	0.045302	-0.045302	0.010515	-0.076744	-0.06594	-0.026126	0.0432889	0.013415	-0.028011	-0.37884	-0.290839	-0.124942	-0.17172	-0.149389
INTERESTING	0.97381	-0.97381	0.039176	-0.039176	-0.004397	-0.086428	-0.058038	-0.038827	0.0526004	0.012315	-0.018724	-0.38932	-0.298884	-0.128398	-0.176474	-0.153522
RELATE- NOTES	0.781171	-0.781171	-0.015706	0.015706	0.000598	-0.057371	-0.099945	-0.104234	0.0865303	0.014969	0.029983	-0.312305	-0.239759	-0.102999	-0.141544	-0.123152
CONFUSING	0.228665	-0.228665	-0.061005	0.061005	-0.000536	-0.077392	0.040043	0.0569819	0.0720494	-0.062034	-0.049639	-0.091418	-0.070182	-0.03015	-0.041423	-0.036049
INCREAS. WORK	0.288094	-0.288094	0.03121	-0.03121	-0.02453	-0.041164	0.050451	-0.024104	-0.059652	0.069331	-0.016374	-0.115177	-0.088423	-0.037986	-0.05219	-0.045418
INTERNET YES	0.024738	-0.024738	0.042127	-0.042127	-0.111682	0.029559	-0.074823	0.1013893	-0.096132	0.023222	-0.075069	-0.064394	-0.026547	0.186859	-0.017885	-0.020226
INTERNET NO	-0.028144	0.028144	-0.034697	0.034697	0.11008	-0.027685	0.076812	-0.104991	0.094408	-0.017787	0.073175	0.060654	0.023598	-0.1888	0.016151	0.041371
E-MAIL YES	-0.007093	0.007093	-0.00564	0.00564	-0.038529	0.083801	-0.021559	0.0297114	0.0011419	0.001268	-0.041853	0.066387	-0.010717	0.037629	-0.040234	-0.079272
E-MAIL NO	0.007093	-0.007093	0.00564	-0.00564	0.038529	-0.083801	0.021559	-0.029711	-0.001142	-0.001268	0.041853	-0.066387	0.010717	-0.037629	0.040234	0.079272
OWN COMPUTER	0.266282	-0.266282	0.12765	-0.12765	0.087852	-0.057229	-0.05367	0.0702904	-0.026758	-0.091966	0.073783	0.007203	-0.332882	-0.109615	0.020206	0.144707
U.S. COMPUTER	-0.283099	0.283099	-0.119698	0.119698	-0.082548	0.053617	0.050489	-0.076153	0.0303063	0.092149	-0.069823	-0.000213	0.337453	0.111657	-0.016997	-0.141617
HOME COMPTER	-0.000712	0.000712	0.005452	-0.005452	-0.032189	0.018391	0.000371	-0.093694	-0.089599	0.052826	0.128536	-0.038958	-0.006591	-0.057055	-0.039154	0.179076
IT Com not enough	0.033247	-0.033247	-0.042007	0.042007	0.065395	0.027854	0.04423	0.0942862	-0.012407	-0.029871	-0.065821	0.013643	0.043995	-0.101461	-0.019246	-0.04457

FORTEST	1-7X/WK	1X/WK-MT	SELDOM	SUM.WORK	INTEREST	REL. NOTES	CONFUSING	INCR. WORK	YES	NO	YES	NO	OWN	US	HOME	COMPs
1																
-0.041132	1															
-0.120615	-0.029178	1														
-0.058461	-0.014142	0.024299	1													
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0.73101	0.17684	0.454479	0.209928	0.95943519	1											
0.632162	0.220449	0.330055	0.030217	0.79327758	0.80218	1										
0.052765	-0.013212	0.312372	-0.018779	0.1515924	0.146378	0.040824506	1									
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-0.042534	-0.059506	-0.004195	0.08051	-0.041868	-0.0416	-0.04848715	0.07521613	-0.011225561	-0.993366	1						
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0.044817	-0.025003	-0.034559	-0.035537	0.01097726	0.00505	-0.02999835	-0.03319988	0.022498634	0.050629	-0.027917	-0.003069	0.003069	-0.026231	-0.01414	1	
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ADDENDUM 3

Self-study package for *How do we do Biology?*

BIOLOGY 124

SELF-STUDY GUIDE

HOW DO WE DO BIOLOGY?

CONTENTS

BIOLOGY 124

The module Biology 124 consists of the following sections, presented here in chronological order :

- Cell Biology – Botany Department – 4 lectures
- Biochemistry – Biochemistry Department – 11 lectures
- Microbiology – Microbiology Department – 10 lectures
- Genetics – Genetics Department – 4 lectures
- ***How do we do Biology? –*** Nature Conservation - 8 lectures
- Evolution – Zoology Department – 4 lectures

WHO SHOULD USE THIS STUDY-GUIDE

This study guide was designed with the following aspects in mind:

- For this section of the module Biology 124 students do not have a textbook or class notes from which to study
- Classes are facilitated in English, which is the second language for the majority of students. This necessitates more intense studying for many students not so fluent in a language other than their mother tongue
- Classes are facilitated for large groups of up to 300 students per session. This limits the contact with the lecturer, and minimizes the time for clarifying dubious parts of the lecture.
- Some students who are repeating the module Biology 124 did not have the same material to study in the previous year, as the programmes of learning are currently adapted on a yearly basis. Moreover, the timetables of such students often do not permit the attendance of all lectures, although tests and examinations are compulsory in the repeated course. Such students will benefit greatly from especially the video-recordings of the lectures.
- Many people not enrolled for the module Biology 124 have expressed an interest in the content of these lectures. The philosophical and innovative approach to teaching statistics to first-year students, and simultaneously introducing them to abstract concepts in research, have evoked much reaction. This study-guide will provide a valuable tool for such individuals.
- Making this study-guide available on the University's computer network (Web-CT) will enable all students enrolled at the University of Stellenbosch to access the information contained herein.
- Putting video recordings of lectures on the intranet (Web-CT) may eliminate the necessity to repeat lectures to different groups of students, as students may be given the choice to either attend the lecture in a lecture hall, or follow the lecturer on video, using the study-guide as facilitator. More time for personal or group consultation with the lecturer may thereby be attained.

HOW TO USE THIS STUDY-GUIDE

This study-guide was designed as a practical tool that would enable Biology 124 students to benefit fully from the content of these lectures, while overcoming the obstacles provided by language, group size, lecture hall facilities, and the unknown territory of philosophical issues in science.

Every lecture is laid out in an identical way, thereby enabling students to start with any lecture, and still know exactly how to access the information. Students are advised to go through the individual lectures in the following way. (Your personal preference and style of studying may differ from the proposed one – as long as you benefit fully from the study-guide, use whatever method suits you best):

Title : Do you recognize some aspects to be discussed in the lecture? Do you have an idea what the content of a lecture with such a title might be?
Aim : Do the key concepts "ring a bell"? Reflect for a few minutes on the concepts to be introduced, and search for any familiarity with the subject.
Background reading : Study the main points in conjunction with the background reading to get a broad view of what is to be introduced in this lecture.
Main points : On DVD in Afrikaans: The key concepts, provided by the overhead transparencies in Afrikaans, together with at least some background reading, will already give you a good foundation for what is to come!
Detailed contents : On DVD in English: The English PowerPoint presentation provides you with slightly more information than the Afrikaans version, and can be quickly scanned before watching the full and detailed version of the lecture on video. Even where the lecture hall is sometimes completely dark, and little can be seen on the video image, the audio is still a valuable enough tool to be used.
Summary and Revision : On DVD : For a quick summary (or refresher after some time) both the Afrikaans and the English PowerPoint presentations can be utilized very effectively.

Think about it ......:

- This part should not be seen as "homework" in the traditional sense. An awakening of your scientific mind is proposed by the questions and tasks. The aim is to make you alert for the role science plays in society, and to integrate your scientific studies with your everyday life.

REQUIREMENTS FOR ACCESSING THE DVD

In this study guide you are provided with a DVD disk containing the following:

- *Lecture 1* to *Lecture 8 and Practical 1* & *Practical 2* in PowerPoint in English
- *Lecture 1* to *Lecture 8 and Practical 1* & *Practical 2* in PowerPoint in Afrikaans (more concise than the English version)
- Video recordings of *Lecture 1* to *Lecture 6* and *Practical 1* & *Practical 2*
- A test in both Afrikaans and English, to assist you in preparation for the examination
- Instructions for the Practical sessions in both Afrikaans and English.

The minimum computer facilities that you should have to be able to access the information available on the DVD are as follows:

Pentium class processor

Microsoft Windows 98, Windows 2000 or Windows NT 40

32 MB of RAM

256 color video display adapter

Video Player capable of MPEG playback, e.g. Windows Media Player

DVD-ROM drive

DVD Media Player

Microsoft PowerPoint and Word

Internet Explorer 4 or higher.

INTRODUCTION TO HOW DO WE DO BIOLOGY?

This is the fifth section in your semester course Biology 124. It constitutes the Statistics section of the module, and presents you with both a philosophical and a practical approach to the application of research in biology.

The section consists of 8 lectures (50 min. each) and 2 practical sessions (3 hours each). The lectures are facilitated in English, with a PowerPoint presentation in English and overhead transparencies in Afrikaans. The latter contains the focal points needed for following the line of thought and main arguments in the lectures, and can be considered as a summary of the lectures.

In the practical sessions elementary experimental design and statistical concepts will be studied. Written reports will have to be handed in at the end of each practical session.

An assignment involving a survey will be given to you during the three-week lecture period. This assignment can be carried out during the rest of the semester, and handed in for assessment in the last week of lectures before the June examination.

AIM OF THIS COURSE

The all-encompassing aim of the section *How do we do Biology?* Is to teach you that

- Biology is exciting
- Progress in science occurs in various ways
- Scientific results do not need to be clear cut ("black and white") in order to contribute to the notion of progress in science
- Various skills fundamental to doing science are harnessed to understand the nature of scientific problems
- Scientific reasoning gave rise to various philosophical issues(e.g. inductive versus deductive reasoning, naïve falsification, burden of proof, parsimony, Occam's razor, etc.)

LECTURES & PRACTICALS

The aim of this series of lectures will be achieved by studying the following case studies and examples:

Lecture 1: *Did the dinosaurs all go extinct at once?*

Lecture 2: *The discovery of DNA – the victory of theory over hard work.*

Lecture 3: *Magic Johnson, Kenyan prostitutes, condoms and the HIV/AIDS Controversy.*

Lecture 4: *Would Jesse Owens (Olympic champion 1936) beat Maurice Green (Olympic champion 2000) in the 100m sprint?*

Lecture 5: *Do men have bigger brains than women?*

Lecture 6: *Gay genes and the Human Genome Project.*

Lecture 7: *Did O.J. Simpson kill his wife?*

Lecture 8: *Is conservation biology science or sociology?*

Practical 1: *Describing data.*

Practical 2: *Testing hypotheses and correlations.*

Lecture 1

Title : *Did the dinosaurs all go extinct at once?*

Aim : This lecture is used as an allegory to cover the issues of induction (i.e. huge numbers of samples of dinosaur fossils found in the same geological stratum) and deduction (i.e. the prediction of a meteorite impact and its subsequent discovery). Subjective versus objective knowledge, hypothesis testing versus theory, as well as naïve falsification will be illustrated by elaboration of the example provided by the title.

Background reading : http://web.ukonline.co.uk/a.buckley/dino.htm

Glen, W. (ed.).1994. *The mass-extinction debates: how science works in a crisis.* San Francisco: Stanford University Press.

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 1: Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 1 (Click on *Lec 1 : Lecture 1 Video*)

PowerPoint presentation in English (Click on *Lec 1: English*)

Summary and Revision : On CD-ROM :

Repeat Overhead transparencies (*Lec 1 : Afrikaans*) and

PowerPoint presentation (*Lec 1 : English*)

Think about it ......:

- *Extraterrestrial collisions capable of causing widespread extinctions pounded the earth repeatedly, causing eruptions and major mass extinctions.* : Search on the internet for any recent additional evidence favouring (or opposing) this theory.
- Keep your eyes open for examples of inductive versus deductive approaches in scientific research. Try to find at least three examples of each during this semester's work.

Lecture 2

Title : *The discovery of DNA – the victory of theory over hard work.*

Aim : This lecture is used as an allegory to teach the value of hypothetico-deductivism. The race to discover DNA will be described as a struggle between empiricists and theorists, while formulation of a null-hypothesis will be illustrated.

Background reading : Watson, J. 1968. *The Double Helix.* Penguin Books.

Jones, S. 2000. *Almost like a whale.* London: Anchor Press.

Jones. S. 1999. *The language of the genes.* London: Flamingo Press.

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 2: Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 2 (Click on *Lec 2 : Lecture 2 Video*)

PowerPoint presentation in English (Click on *Lec 2 : English*)

Summary and Revision : On DVD :

Repeat Overhead transparencies (*Lec 2: Afrikaans*) and

PowerPoint presentation (*Lec 2 : English*).

Think about it ......:

- Did Watson & Crick "steal" the ideas of other researchers? Write a short paragraph stating your view, referring to the definition of hypothetico-deductivism.
- *If I have reqched great heights, it is because I have stood on the shoulders of* giants *(Isaac Newton).* Keep your eyes and ears open throughout your introduction to new development in research for more cases confirming this statement.

Lecture 3

Title : *Magic Johnson, Kenyan prostitutes, condoms and the HIV/AIDS controversy.*

Aim : The issue of the burden of proof is covered in this lecture. The functioning of the HI virus, and establishment of a connection between HIV and AIDS will be discussed. The continuous nature of scientific research will be emphasized.

Background reading : **http://www.avert.org**

Rose, S. 1997. *Lifelines : biology, freedom, determinism.* London : Penguin Books.

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 3 : Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 3 (Click on *Lec 3 : Lecture 3 Video*)

PowerPoint presentation in English (Click on *Lec 3 : English*)

Summary and Revision : On DVD:

Repeat Overhead transparencies (*Lec 3 : Afrikaans*) and

PowerPoint presentation (*Lec 3 : English*).

Think about it ......:

- What is the view of president MBeki on HIV/AIDS? Do a literature search, and write a short paragraph to clarify his viewpoint for yourself.
- Is the use of condoms an efficient way of preventing the spread of the HI virus? What type of campaign would you suggest to prevent its spread?

Lecture 4

Title : .*Would Jesse Owens (Olympic gold medal 1936) beat Maurice Greene (Olympic gold medal 2000) in the 100 m dash?*

Aim : The value of contemporaneous controls and replication is illustrated in this lecture. The fundamental role of experimentation, the value of replication, pseudo-replication, experimental design and reliability will be discussed.

Background reading : http://www.jesseowens.com

Gould, S.J. 1981. *The mismeasure of man.* London : Norton Press.

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 4 : Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 4 (Click on *Lec 4 : Lecture 4 Video*)

PowerPoint presentation in English on (Click on *Lec 4 : English*)

Summary and Revision : On DVD:

Repeat Overhead transparencies (*Lec 4 : Afrikaans*) and

PowerPoint presentation (*Lec 4 : English*).

Think about it ......:

- Write a paragraph on the purpose of replication in research, and the pitfalls leading to pseudo-replication.
- Be on the lookout for statements on performance (and other) evaluation, where the fundamental rule of experimentation (i.e. the existence of contemporaneous controls) was violated.

Lecture 5

Title : .*Do men have bigger brains than women?*

Aim : The issue of inherent biases and prejudice in science is covered in this lecture. Differentiating between cause and effect, the existence of pseudo-correlations, bias by statistical artefact, inappropriate conparison, confounding factors and Simpson's paradox will be illustrated in this lecture.

Background reading :

Mayr, E. 1991. *One long argument: Charles Darwin and the genesis of modern evolutionary thought.* New York: Harvard University Press.

Sagan, C. 1977. *The dragons of Eden : speculations on the evolution of human intelligence.* London: Hodder & Stoughton Ltd

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 5 : Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 5 on (Click on *Lec 5 : Lecture 5 Video*).

This lecture continues into the next lecture, i.e. the last 4.5 minutes of Lecture 5 can be viewed by clicking on *Lec 6 : Lecture 6 Video* on the DVD.

PowerPoint presentation in English (Click on *Lec 5 : Lecture 5 English*)

Summary and Revision : On DVD:

Repeat Overhead transparencies (*Lec 5 : Afrikaans*) and

PowerPoint presentation (*Lec 5 : English*).

Think about it ......:

- *There are lies, damn lies, and statistics.....* Write in your own words a definition on pseudo-correlation, providing three examples that confirm the above quotation.
- What does the above-mentioned tell you, i.e. how does it warn you about the misuse of statistics?

Lecture 6

Title : .*Gay genes and the Human Genome Project.*

Aim : The issues of "hard" scientific evidence and environmental versus genetic control of behavior are covered in this lecture. The scientific conflict over reductionism and holism will be discussed.

Background reading :

www.ornl.gov/hgmis/project/info.html

Marais, E. 1971. *The soul of the white ant.* Cape Town : Penguin Books,

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 6 : Afrikaans*)

Detailed Contents : On DVD:

Video recording of Lecture 6 (Click on *Lec 6 : Lecture 6 Video* – Lecture 6 starts after 4.5.minutes, as Lecture 5 was concluded in this lecture hour.)

PowerPoint presentation in English (Click on *Lec 6 : English*)

Summary and Revision : On DVD:

Repeat Overhead transparencies (*Lec 6 : Afrikaans*) and

PowerPoint presentation (*Lec 6 : English*).

Think about it ......:

- The School for Biological Sciences at the University of Stellenbosch is situated in the J.C.Smuts building. Do a concise literature search on the theory of holism, as propagated by J.C.Smuts.
- What is your view on the Human Genome project, and the publicity given to the completion of deciphering the genetic code? Is the race really over, or has it actually just begun?

Lecture 7

Title : *Did O.J. Simpson kill his wife?*

Aim : This lecture will cover the issue of scientific evidence (DNA), parsimony, Occam's razor and the value of scientific evidence in the world at large. The formulation of null and alternative hypotheses, as well as types of error resulting from unreliable evidence will be discussed. The obligation to "translate" science into a generally/publically understood form will be emphasized.

Background reading :

http://www.members.ozemail.com.au/~dtebbutt/oj/ojindex.html

Bodmer, W. & McKie, R. 1994. *The book of man : the Human Genome Project and the quest to discover our genetic heritage.* Oxford : Oxford University Press.

Brockman, J. & Matson, K. (eds). 1997. *How things are : a science tool-kit for the mind.* London : Phoenix Books.

Main points : On DVD:

Overhead transparencies in Afrikaans (Click on *Lec 7 : Afrikaans*)

Detailed Contents : On DVD:

No video recording of Lecture 7 is currently available.

PowerPoint presentation in English on (Click on *Lec 7 : English*)

Summary and Revision : On DVD :

Repeat Overhead transparencies (*Lec 7 : Afrikaans*) and PowerPoint presentation (*Lec 7 : English*).

Think about it ......:

- Do you think science has an obligation to make itself understood to the general public?
- Search for cases where scientific evidence was used as final incrimination in a court case.

Lecture 8

Title : *Is conservation biology science or sociology?*

Aim : This lecture will be used as an allegory to cover the issues of the relative merits of experimentation and observational studies, and will address the need to combine science with public policy in order to make science worthwhile. Problems of laboratory experiments, field experiments, natural experiments and uncontrolled observations are highlighted with applicable case studies.

Background reading : http://www.mcgill.ca/Biology/undergra/c365a/aims.htm

Dobson, A.P. 1998. *Conservation and biodiversity*. New York: Scientific American Library Press.

Meffe, G.K. & Carroll, C.R. 1997. *Principles of Conservation Biology.* London: Sinauer Assoc. Press.

Primack, R.B. 1998. *Essentials of Conservation Biology*. London: Sinauer Assoc. Press.

Main points : On DVD :

Overhead transparencies in Afrikaans (Click on *Lec 8 : Afrikaans*)

Detailed Contents : On DVD:

Currently no video recording of Lecture 8 is available.

PowerPoint presentation in English (Click on *Lec 8 : English*)

Summary and Revision : On DVD :

Repeat Overhead transparencies (*Lec 8 : Afrikaans*) and

PowerPoint presentation (*Lec 8 : English*).

Think about it ......:

- A new National Park, also called a "Peace Park" is developed on the borders of South Africa, Zimbabwe and Mozambique. Is this development for conservation or pure sociology? What other factors may be at stake? (Look at the role players, the financial and political stakeholders, etc.)

Practical 1

Title : *Describing data*

Aim : The first Practical session will deal with the description of data. Students will be introduced to different types of data, as well as elementary statistical concepts like variable, mean, median and mode. Measures of variability (i.e. standard deviation, coefficient of variation and optimal sample size), as well as different ways to represent data graphically (e.g. box-and-whiskers plot, histogram and scatter plot) will be explained.

Background reading :

http://www.utexas.edu/courses/bio301d/sciencelaw.html

Krebs, C.J. 1993. *Ecological methodology.* New York: Harper & Row.

Contents : On DVD:

Video recording of Practical 1 (Click on *Prac 1: Practical 1 Video*)

PowerPoint presentation in English (Click on *Prac 1: English Presentation*).

Practical session: On DVD :

English instructions: Click on Prac 1 : English Laboratory Instructions

Afrikaans instructions: Click on Prac 1 : Afrikaans Laboratory Instructions

Practical 2

Title : *Testing Hypotheses and Correlations*

Aim : In the second Practical session students will be introduced to concepts like null hypothesis, probability, significant difference, correlation coefficient and regression line. Of students will be expected to test for the difference between the means of two equal-sized samples of continuous-data observations, and to calculate the relationship between two variables.

Background reading :

Zar, J.H. 1984. *Biostatistical analysis*. London: Prentice-Hall.

Contents : On DVD:

Video recording of Practical 1 (Click on *Prac 2: Practical 2 Video*)

PowerPoint presentation in English (Click on *Prac 2 : English Presentation*)

Practical session: On DVD :

English instructions: Click on Prac 2 : English Laboratory Instructions

Afrikaans instructions: Click on Prac 2 : Afrikaans Laboratory Instructions

ASSIGNMENT:
DESIGN A SURVEY

You have to do only one survey, i.e. either Survey A or Survey B.

The topic for Survey A has been chosen with the male students in mind, while the topic of Survey B will concern mainly female students. However, feel free to do the survey of your choice. You do not need to carry out the survey in practice, but only to design it, providing answers to the stated questions. Hand in the design of the survey together with your last practical report during your last practical session.

A. *Design a survey to examine condom use by students on the campus of the University of Stellenbosch.*

Provide answers to the following questions:

- How would you test whether men use condoms to prevent pregnancy or HIV infection?
- If students use condoms for fear of HIV infection, would you expect those with long-term partners to use them more/less?
- What biases could occur if you ask people directly if they use condoms?
- Would an anonymous survey help?
- Where would you look for data to compare your results with?

Instructions for Survey A can be viewed on the **DVD.**

Click on **Lec 3 : Lecture 3 Video** and watch from **38:10 to 40:30** minutes.

B. *Design a survey to examine the existence of synchronous cycles on the campus of the University of Stellenbosch.*

First read the following article, which is included in this study-guide :

McClintock, M.K. 1971. Menstrual synchrony and suppression. *Nature* 229: 244-245.

Provide answers to the following questions:

- Do you expect women in different residences to have similar cycles?
- Will students who live at home have synchronous cycles with other women?
- Will women in mixed (men/women) residences have shorter cycles than women in women-only residences?
- Will the use of the contraceptive pill confound the issue? If so, how would you avoid this in your data processing?
- Should you find more synchronous cycles later in the year?

Instructions for Survey B can be viewed on the **DVD**.
Click on **Lec 3 : Lecture 3 Video** and watch from **44:00 to 47:00** minutes, i.e. the last minutes of the lecture.

SELF-EVALUATION

The following is an example of what can be expected in a written examination paper. This is included for you to evaluate your own performance in your preparation for the examination.

Test : On DVD :

Click on Test : English for instructions in English

Click on Test : Afrikaans for instructions in Afrikaans

Assessment of the section *How do we do Biology?* : You will get one opportunity to complete a written examination for the section *How do we do Biology*. Your mark for the written examination will constitute 70% of your final mark for this section. The remaining 30% will be made up by the two practical reports plus the design of the survey (see p. 20-21).

ACKNOWLEDGEMENTS

I wish to express my gratitude to my study leader, Prof. Eli Bitzer, for his guidance, criticism and advice. Prof. Chris Kapp is also thanked for his valuable contribution to my MPhil studies.

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My sincerest gratitude is extended to my husband and sons who surround me with love, encouragement and enthusiasm. Thanks for the help with the video-editing, web-page and DVD – and for coping with an increasingly exhausted mom. Pierre, Niels, Dieter and Pierre-Henri : you're a great family, and this is for you!