Teaching Statistics to Freshman Microbiology Students

Lydia-Marie Joubert[1] & David Ward[2]

[1]Stanford University Medical School, STANFORD, CA & [2]Dept Conservation Ecology, Stellenbosch University, SA

ostract

w programmes of learning implemented at the University of Stellenbosch, South Africa, uded statistics to freshman students in a multidisciplinary biology module, involving dents majoring in various disciplines of biological sciences and biotechnology. Not only is istics part of most aspects of data interpretation, but also an integral part of experimental ign and scientific reasoning. However, in the past students in the biological sciences were oduced to statistics only during their graduate years, often with limited undergraduate thematical teaching. Our approach included a series of 8 one-hour lectures and two three- r practical sessions to 600 freshman students, introducing them to interesting case dies on 'hot topics' in which statistics provided a valuable tool to solve the case. othesis testing, induction versus hypothetico-deductivism, naïve falsification, formulation null-hypothesis, pseudo-replication, statistical artifact, Occam's razor and the value of ntific evidence in the world at large were discussed. The existing language barrier in an kaans and English speaking audience was overcome with dual projection screens for both guages, and video-recording of the series to be available in digital format for students' nds. The objective was to stimulate and motivate students for a scientific and statistical y of thinking, and to explore and recognize scientific reasoning in both science and ryday life. The promotion of lasting learning by active involvement in thinking was vided in the practical sessions where basic data was obtained and analyzed to construct r own knowledge. Assessment and student feedback indicated that the learning outcomes e largely reached. Practical obstacles may furthermore be overcome by application of nology and motivated involvement.

troduction and Background

e accumulation, manipulation and comprehension of data is essential in scientific disciplines. The scientist's search for meaning is invalidated hout the power of statistics. Yet students in the biological sciences en have limited formal exposure to statistics during their high school d undergraduate studies.In the new programmes of learning at the iversity of Stellenbosch, South Africa, a multidisciplinary module ology 124 was designed to include an introduction to Statistics to shman students in the Biological Sciences, together with their roduction to Cell Biology, Biochemistry, Microbiology, Genetics and ology. The course "**How do we do Biology?**" focused on training in tistical thinking, with the goal to encourage and develop a statistical proach to data, as well as experience with how statistics can be used to swer scientific and everyday questions. The course was developed to place a Statistics module fraught with problems, low scores (53% mean midterm and 35% at finals) and negative student feedback.

Aim

To teach students that:

- **Progress in science occurs in various ways**
- **Scientific results do not need to be clear-cut 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)**
- **Biology is exciting**

Learner Group

- The group consisted of 570 freshman biology students, following different programmes of learning in Biological Sciences, Agriculture, Forestry, Life Sciences, Consumer Sciences and Biokinetics.
- All students completed 5 years of High School Math, but not all had the same level of Biology, Physics and Chemistry education. Most had limited previous exposure to statistical data analysis.
- While all other lectures were presented in two sessions in two official languages (English and Afrikaans), the course content and objectives demanded this lecture series to be facilitated to a single large group. Language barriers were overcome by giving lectures as PowerPoint presentations in both Afrikaans and English, using dual projection screens.
- Assessment was bilingual, and though instruction was in English, conversation, assignments and reports were carried out in both languages.
- Only one lecturer was involved in the academic lectures, and two lecturers, with graduate student assistants, in practical laboratory sessions. Professional support staff, as well as teaching and technical assistance allowed us to create exemplary and effective learning environment in the lab.
- Application of new instructional technologies, aimed at enhancing information presentation, proved to be invaluable. Facilitating lectures to large classes is a well-documented problem[1], which was here ingeniously solved by applying suitable technology to a diverse group from various cultural and academic backgrounds.

Objectives

- The main objective was not to introduce students to statistical formulae, mathematical functions or analytical software, but to introduce them to a statistical way of reasoning in science, by illustrating to them how statistics can be applied to answer scientific questions.
- By motivating students with a limited background to theoretical statistics, to recognise and explore a scientific way of reasoning, student learning would be produced in a cooperative and supportive learning environment, as suggested by the learning paradigm described by Barr and Tagg[2].
- As lasting learning is promoted when students are actively involved in thinking about what is being heard, seen or done[3] the practical sessions would provide an excellent milieu to create a learning environment in which constructivism comes into practice.
- Students would be introduced to basic processes of data collection and analysis, requiring minimal equipment. They worked in discussion groups, assisted by graduate students skilled in data analysis.
- In their cognitive interaction with data, as well as other students and lecturers in the lab, students were enabled to construct their own knowledge, associate it with prior knowledge, and thereby attain real understanding of new concepts.

Implementation:

- Eight theoretical lectures with striking and imaginative titles, appealing to the interest of the students, were chosen as topics to illustrate how statistics can be used to answer questions in scientific and everyday life. These one-hour lectures revealed to students how various skills fundamental to doing science are harnessed to understand the nature of scientific problems, and also covered the most important philosophical issues.
- Two three-hour lab sessions were devoted to introducing students to the collection and processing of real data. The first hour was spent on an introductory lecture on how data was to be collected and processed, and on what logical principles the statistical formulae were based. Four graduate students per lab of 80 freshmen were involved in assisting students.
- Audio and video recordings of lectures were made available on CD and DVD to give current and previous students, as well as other interested students and faculty members, access to the lecture and discussion content.
- Audio recording were available on the Intranet (Web-CT) of the University of Stellenbosch, and downloaded by 80% of the students within the first week of availability. Asynchronous repetition of lecture material provided this way was ingenious and imperative in a scenario where no textbook or class notes was available, lectures were facilitated in the second language of the majority of students, and most students were only introduced to statistical concepts in their freshman year.

Assessment:

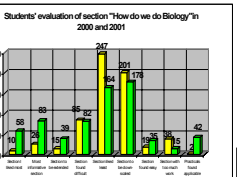
The students' work was assessed in a singe theoretical examination with multiple choice questions. A written lab-assignment, as well as a written report on a survey that had to be planned through all stages up to the implementation stage, were evaluated for the final mark.

Feedback

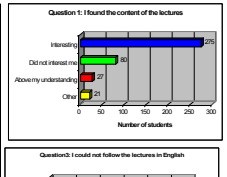
- Student feedback was obtained by questionnaires at the end o first semester of teaching.
- Students responded positively towards statistics, indicating thi second most informative (after Microbiology) and best-liked Bi section, and rating it third under 'most wanted to see extended
- Though it was still rated as the third most difficult section, scor climbed to the top of 6 sections offered in this module (Fig 2).
- The majority of students found the lectures interesting (Q1), stimulating (Q2), with the practicals relating well to the theory (
- Few students had problems following in their second language and their apprehension about the lack of a textbook was addre compilation of an audio CD and availability of lectures on Web
- Comments on evaluation sheets varied from 'a complete waste time' (one case), to 'interesting and stimulating', 'very cool', 'w loved it!', 'good to see theory in practice - will help me in resea day', and 'I enjoyed theory and practical immensely, and would complement prof Ward on his choice of materials and presenta This indicates a marked positive change from the previous ye
- Though the main task is not to improve enjoyment and popular programmes, but to improve the level to which learning is proc and to enhance the facilitation of quality learning, enjoyment m follow once powerful learning environments are created and st start achieving success by constructing their own knowledge.

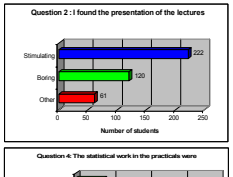
Reflection

- The essential process of higher education is the transformation information into knowledge and knowledge into insight[4]. Biolo provided us with a platform to promote various new approache lecture facilitation.
- Lectures were facilitated under the learning paradigm, with a h approach to teaching and learning, and integration of theoretic practical sessions
- Practical sessions were facilitated using constructivist-based a and cooperative learning, thus creating powerful learning environments.
- Lecture facilitation for a very large class was promoted applyin available technology and support staff and students, as well as application of Web-CT and compilation of a CD with lecture co
- Information technology is a transformation agent affecting ever and constitutes a paradigm shift in higher education. It allows u focus on productivity, and to customize education, to provide c and to allow students access to lecturers and classes asynchro with lecture presentation. Our mission is to produce quality lea and the quality of our exiting students will be the criteria for ou success. This new approach to statistics teaching may inspire initial awakening of our freshman university students to the po learning environment that an institute of higher education can



Question1-4:





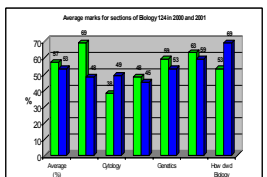
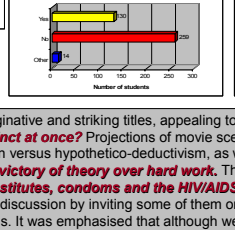
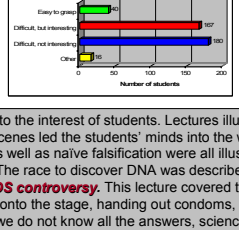


Figure 2:





References: **1. Gillespie**, F. 1996. Teaching Excellencs 8(5): 1996-1997. **2: Barr, RB & Tagg, J**. 1995. Change 27(6): 13-25. **3. Lord,TL**, 2001, The American Biology Teacher 63: 30-38.2 **4. Tuller, C.** 1997. The learning revolution: The challenge of information Tehnology in the Academy.Anker Publ

w do we do Biology?

opics in this lecture series have imaginative and striking titles, appealing to the interest of students. Lectures illustrate 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.

ure 1: Did the dinosaurs all go extinct at once? Projections of movie scenes 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 knowle thesis testing versus theory, induction versus hypothetico-deductivism, as well as naïve falsification were all illustrated by elaboration of this example.

ure 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.

ure 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 con criticized. Students were drawn into discussion by inviting some of them onto the stage, handing out condoms, and filling them 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 ency against infection by the HIV virus. It was emphasised that although we do not know all the answers, science is actively involved in the pursuit, and the search is continuing.

ure 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 bility were discussed.

ure 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 illus ecture.

ure 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 lopment. These arguments fit into the bigger picture of scientific conflict over reductionism and holism.

ure 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 a e 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

ure 8: Is conservation biology science or sociology? Problems of laboratory and 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 ill lusion.

tical 1: Describing data: Students were introduced to different types of data, statistical concepts and measures of variability, as well as ways to represent data graphically.

tical 2: Testing Hypotheses and Correlations: Students were introduced to concepts of null hypothesis, probability, significance, correlation and regression.