Educational robotics: instructional technology to unify diversity of computing topics into a single cohesive unit

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Introduction

In computing studies at tertiary level, students are often taught different computing subjects as individual and distinct units. Often than not, these subjects are taught without any relationship to each other. This paper introduces a curriculum that shows how educational robotics, employing construction kits such as *Lego Mindstorms* (Lego, 2002) and *Fischertechnik* (2002), can be used as instructional technology to unify diverse computing and technical topics into a single comprehensive and cohesive unit. The advantages of this approach are many. In practical terms, students are directly involved in the design and development of hardware and software devices using the knowledge they have acquired as prerequisite. The very essence of computing using robotics appeals to a large student audience and teachers alike. In addition, by playing a reversed role, educational robotics can be employed as a platform for problem-based learning. Here, the flexibility of an educational robotics curriculum becomes evident – not only does it serve as a unifying factor for computing and technical topics, but the course itself serves as an instructional medium for the student's incomplete prerequisites.

Curriculum

This section briefly describes a curriculum for a 12-week term course on educational robotics. The curriculum is suitable as a special topic offered to third year or Honours level undergraduates. The prerequisites required are a working knowledge of the following areas: programming languages (i.e. C/C++, *Visual Basic*, Forth, ADA and Java), programming methodology (i.e. linear programming, concurrent programming, data structures), intelligent systems methodology, Boolean algebra, image processing, electronics and mechanical engineering. However, these prerequisites are not compulsory and serve only as a guideline. In such cases where students do not possess the proper prerequisites, this course should be undertaken with the understanding that the curriculum is to be approached as a problem-based learning project. That is, the student is required to take the initiative to obtain the necessary knowledge throughout the duration of the course. The recommended text for this course is by Ferrari, Ferrari and Hempel (2002).

Week 1 – Introduction
Introduces the student to the art and science of constructing and programming robots. This includes a description of the necessary software and hardware resources available for development of robots required for this course. Students are allowed to familiarise themselves with the construction kits.

Weeks 2 to 3 – Mechatronics Part 1: Engineering
Students are taught the fundamentals of building components required to construct robots. Specific mechanical design principles specific to robotics are taught, such as articulated joints, gear trains and pneumatics.

Weeks 4 to 5 – Mechatronics Part 2: Electronics
Electronics specific to robotics are taught to the students. Special focus is placed on different types of motors, sensors and micro controllers. However, generic electronic skills are also taught so third party components can be used to supplement parts that are unavailable from the recommended construction kits.

Weeks 6 to 7 – Software
Students are taught how to interface, control and communicate with robots via a computer. They will be introduced to software resources and tools such as, *NQC*, *LeJOS*, *legOS*, *pbForth*, *ADA for Mindstorms*, *RoboLab*, *LLWin*, *Spirit*, *Mindstorms SDK*, standard programming languages and other proprietary software tools.

Week 8 – Types of robots
Different categories of robots are introduced. This includes autonomous robotics, industrial robotics, mobile robotics, competition robotics, and entertainment robotics. Students are directed to appreciate the advantages and the functions of each type of design.

Weeks 9 to 10 – Advanced programming techniques
Advanced programming techniques are incorporated into the design of each type of robot. Intelligent systems techniques such as fuzzy logic, neural networks and genetic algorithms are embedded into the controller software to make the robots 'smarter'. Concurrent programming is also introduced to multitask the robot's functions.

Weeks 11 to 12 – Project
Towards the end of the course, three weeks (as there are no examinations for this course, the extra examination week is used for project activity) are allocated to the students to work on a project assigned to them or of their own choosing. The project work should include hardware, software and programming methodology of robotic design and construction. The project should be undertaken by groups of two to four students each.

Assessment
Assessment is based entirely on practicals and project work. The total achievable score for this course is 100. A score of up to 5 is allocated to each student per week from week 2 to week 10. This gives a possible 45 for nine weeks. Marks are given according to the student's performance and initiative. Marks should not be allocated based entirely on the level of knowledge of an individual student as some may not have the necessary prerequisites. The remaining 55 marks are given based on the final project. Of these, 20 marks are allocated for hardware construction and design. The marking criteria are based on the efficiency, elegance, ingenuity and resourcefulness of each robot design. 20 marks are allocated for the software component of the robot's function. The marking criteria are based on code optimisation and programming techniques used. Special attention is paid to the use of intelligent systems technology. 10 marks are allocated for documentation. The remaining 5 marks are for teamwork.

References

Ferrari, M., Ferrari, G. and Hempel, R. (2002) *Building Robots with Lego Mindstorms*. Rockland, MA: Syngress Publishing.

Fischertechnik (2002) [Online] Available: http://www1.tpgi.com.au/users/p8king/ [2002, April 28].

Lego (2002) [Online] Available: http://www.lego.com/mindstorms/ [2002, April 25].

Types of projects to facilitate the teaching of educational robotics

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Introduction

Educational robotics as an instructional technology helps to unify the diversity of computing and technical topics into a single cohesive unit. Delivered as a problem based learning unit, different types of robotic projects can be extensively used to demonstrate individual design and construction technology using specific hardware and software development tools. These projects are to be carried out as third year or Honours level programs. The contributions from these projects as part of educational robotics in an instructional technology curriculum are significant.

Construction kits

All the projects described in this paper are designed using construction kits manufactured by *Lego* (2002) and *Fischertechnik* (2002). The main advantages of using these kits are accessibility, flexibility and reusability. The *Lego Mindstorms* kit consists of *Lego*'s range of building and electronic components. Included in the kit is a specially developed micro controller called the RCX, encased to look like a large *Lego* brick. The *Fischertechnik* range of construction kits for robotics has been used by heavy industries as a prototyping tool for the design of industrial robots. Robots built from these construction kits can be programmed and controlled from a computer.

Robot categories

Robots can be basically categorised into two main categories: industrial robots and autonomous robots. Industrial robots are static. With the exception of articulated joints like grippers, elbows and turn-tables, these robots do not move from the location it has been originally positioned. The controllers are normally situated apart from the actual robot, linked by physical communication cables. Autonomous robots are independent free-roaming robots. In most cases, these robots either have wheels, tractors or legs to facilitate mobility. The controllers can be found onboard the actual robot's construction.

Types of projects

The different types of projects are classified as simple, intermediate or advanced. This classification is determined either on the complexity of its construction or on the programming techniques required to control the construction. Only in rare cases are both construction and software rated at an advanced level.

Type 1 – Industrial robots (static robots)
These robots normally have a pneumatically operated arm with three degrees of movement: turn left or right; tilt up or down; and a gripper that opens or closes. As its name suggests these robots are used in manufacturing industries to move heavy loads in a pre-determined three-dimensional space. The programming techniques used are simple repetitive linear programming. Construction: Advanced. Programming: Simple.

Type 2 – Walking robots (mobile robots)
Walking robots are perhaps one of the most challenging robotic constructions that can be undertaken. The project covers bipeds (two-legged), quadpod (four-legged), six-legged and hexapods (eight-legged) robots. The software development is however quite basic as it only requires sequential programming to control the movement of each leg in sequence. Construction: Advanced. Programming: Simple.

Type 3 – Competitive robots (mobile robots)
Competitive robotic projects are probably the most popular forms of robot application. This category covers soccer robots, robot maze and search-and-rescue robots. The objective of these competitions are respectively to: score the most goals; traverse a maze in the quickest time; and gathering the most number of objects from pre-determined space. The construction is fairly simple consisting of wheeled vehicles. However, its programming involves some of the most advanced techniques available using fuzzy logic, neural networks and genetic algorithms. Construction: Simple. Programming: Advanced.

Figure 1. (Left) A *Lego* mobile robot in the form of a prototype car modified to hold an RCX with three motors and four sensors to control steering. (Right) A *Fischertechnik* industrial robot arm with articulated joints.

Type 4 – All-terrain explorer (mobile robots)
This project involves the construction of mobile robots that can explore and navigate their way through uncharted space, avoiding and extracting themselves from obstacles. Most of these vehicles are either wheeled or tracked with novel methods of manoeuvring. Its programming involves an advanced level of intelligent systems technology. Construction: Intermediate/Advanced. Programming: Intermediate/Advanced.

Type 5 – Cooperative-collective robots (static and mobile robots)
This project involves a collection of robots. Their main purpose is to explore an uncharted space collectively, communicating and data-logging its finding with other robots in the collective. Basically a main static robot would act as the main station, controlling smaller but more mobile robots as an extension of itself. This project is perhaps the most challenging in both aspects of robotics construction and programming. Construction: Intermediate/Advanced. Programming: Advanced.

References

Fischertechnik (2002) [Online] Available: http://www1.tpgi.com.au/users/p8king/ [2002, April 28].
Lego (2002) [Online] Available: http://www.lego.com/mindstorms/ [2002, April 25].

Teaching In Faculties: Making science relevant for professional degree programs

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The Faculty of Science teaches in many professional degree programs especially in first year. These units of study are mostly mainstream, and hence not customized for the clients. The short term aims of this project are to:

- improve the first year experience for students in client faculties;
- develop targeted units of study for professional degree programs;
- define models of 'approaches to delivery' that are transferable to other disciplines; and
- raise staff awareness of the needs of incoming students.

The long term aims of this project are to ensure:

- sustainable ongoing delivery of quality focused learning experiences to students in professional degree programs; and
- effective liaison with client faculties for ongoing developments.

This project targets the student learning experiences in four professional degree programs.

Biological Sciences delivering to Education students. The objectives are to:

- customize an existing unit of study to make it more appropriate and relevant for BEd Human Movement and Health Education students; and
- design the model so as to enable its transfer to other client faculties (e.g. Biology for Agriculture, Biology for Nursing, Physics for Education).

Chemistry delivering to Agriculture students. The objectives are to:

- convert a suite of *ChemCAL* modules to an online format so that they can be accessed and used by students any time, any place;
- tailor the *ChemCAL* modules to better suit the targeted units of study and the School of Chemistry's teaching philosophy; and
- make the modules available to more students and the content more relevant to the students' learning.

Mathematics and Statistics delivering to Engineering students. The objectives are to:

- develop web-based packages of components of first year mathematics material that can be used within Engineering to better meet the needs of all Engineering students; and
- develop a pilot compiler that will package the modules with a layered interface to allow for flexible use by students and delivery via *WebCT*.

Physics delivering to Agriculture students. The objectives are to:

- move to more appropriate and more flexible delivery of the physics material within an agriculture unit of study;
- identify topics within *Climatology* and *Agricultural Environment and Equipment* that would be better delivered via the Web than via lectures; and
- develop web-based materials to cover these topics.

The project is based on an action research model with in-depth evaluation of the teaching reforms and associated learning outcomes as a priority. The evaluation strategy for the project uses Kirkpatrick's four-level model as a guide. Our interpretation of the model is:

Level 1 – *reaction* – measure of student satisfaction

Student surveys were administered at the end of semester 2, 2001 in three of the four sub-projects. Information obtained through this level of evaluation will be used to:

- guide modification of and enhancement to the teaching materials;
- guide changes aimed at improving the student learning experiences within the targeted first year units of study; and
- assist in evaluation of the underlying models for teaching reform.

Level 2 – *learning* – measure of skills and knowledge learned

This evaluation is being conducted within the sub-projects by the academic staff involved with the students. Qualitative comparisons are being done between the 2000 student cohort who were not exposed to the teaching innovation and the 2001 student cohort after the introduction of the teaching innovation. Information obtained through this level of evaluation will be used by teaching staff to:

- consider possible modifications to their teaching practices; and
- review the alignment between the unit of study objectives and the teaching materials and learning experiences being offered.

Level 3 – *transfer* – measure of transfer of the knowledge, skills and understanding gained in the first year unit of study to an appropriate second year unit of study

The results of a survey that looks at the student's awareness of a strong relationship between the first year unit of study and the professional program will be correlated with the student's overall performance for the second year unit of study. Information obtained through this level of evaluation is:

- testing the alignment between the contextualised first year general science units of study and the second year professional degree units. If successful, the students will benefit by having a better understanding of the relevance of the discipline area within their professional degree program.

Level 4 – *dissemination and value to the organization* – measure of cost effectiveness and organizational benefits

Evaluation for this level is in the form of focus questions. Information obtained through this level of evaluation will be used to:

- demonstrate to the University that cross-discipline projects, such as this one, can, not only be successful, but also deliver long term benefits.

There are three emerging models for approaches to curriculum and delivery reform that may be transferred to other disciplines.

Model 1 (being implemented by the School of Biological Sciences) – This model took the approach of 'value adding' to an existing unit of study. This involved some modification to the content and some focus on the professional pathway of the student cohort.

Model 2 (being implemented by the Schools of Chemistry and Physics) – This model consists of modules within a unit of study (with the potential to be modules across units of study for just-in-time learning, revision, or core topics).

Model 3 (being implemented by the School of Mathematics and Statistics) – This model consists of packages of material which are to be used both within a unit of study (first year Engineering students) and across units of study (just-in-time revision for third year Engineering students).

References

Kirkpatrick, D. (1994) *Evaluating Training Programs: The four levels*. San Francisco: Berrett-Koehler.

Kirkpatrick, D. (1996) Techniques for evaluating programs, part of Great Ideas Revisited series in *Training & Development*, January, 54-59.

Kirkpatrick, D. (1996) Revisiting Kirkpatrick's four-level model, part of Great Ideas Revisited series in *Training & Development*, January, 54-59.

Prosser, M. and Trigwell, K. (1999) *Understanding Learning and Teaching: The experience in higher education*. Buckingham: SRHE and Open University Press.

Using the web to enhance laboratory teaching

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Course structure

At The University of Sydney chemistry is taught as a practical based discipline and students spend approximately three hours each week in the laboratory. The laboratory component of the course is structured in three parts: the pre-laboratory work; a series of laboratory exercises; and the post-laboratory work.

- The students conduct the pre-laboratory work in their own time, prior to their scheduled laboratory class. The purpose is to provide background and theoretical backup to the experiment that will be conducted that week. The information is supported by a number of questions designed to test the comprehension of the student.
- The laboratory work is conducted in a three-hour block and introduces the students to important practical techniques as well as providing some experience of the concepts taught during lectures.
- The post-laboratory work is brief and usually consists of an analysis of the results obtained in the laboratory or a supporting problem. This is conducted in the student's own time.

Online pre-laboratory work

When the pre-laboratory work was print based, the laboratory tutors checked the work of each student at the start of the laboratory class. This took considerable time and detracted from the time available to conduct experimental work. We set out to design a means of hosting the pre-laboratory work online. This was to be coupled with a formative quiz, which could give feedback to the students at the time they were thinking about the material and alert tutors to individuals that might be having difficulties with a particular area. All of the time in the laboratory would then be available for practical work with the tutors able to focus on teaching practical skills.

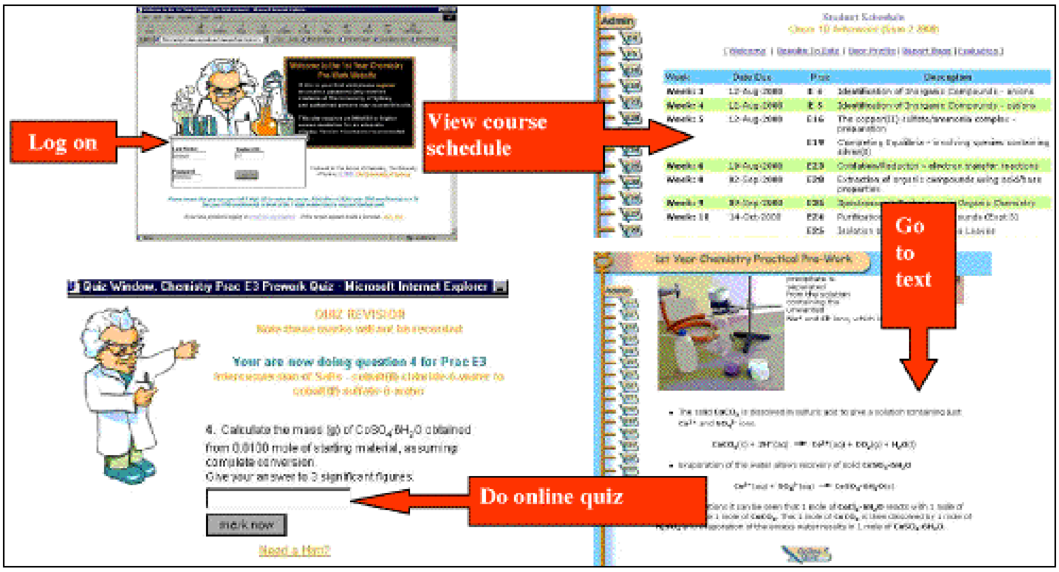

Figure1. Example of online pre-laboratory work page sequence

The online quiz

The students are required to complete the pre-laboratory work before coming into the laboratory and compliance with this is taken as submission of the online quiz associated with each practical exercise. Each quiz has a 'due by' date to coincide with the date of the laboratory class. A student may complete the quiz after the due by date but the marks are not recorded. Similarly a student may return to any quiz for revision purposes and their marks are not recorded. The quiz contains between 3 and 10 questions. The quiz is intended to be formative in nature while still providing an incentive to the student to make an attempt at each question. If the student scores above 20% on the quiz they are given full marks for completing the pre-laboratory work. If a student scores less than 20% (likely if they randomly select each answer) they are credited with the quiz mark they obtained for completing the pre-laboratory work. The students see the mark they scored at the end of the online quiz and can compare it with the class average and the top mark, which are calculated at the time.

Student evaluation

Evaluation is, of course, an integral part of any development. An evaluation module was built into the application to request information of a technical and of an educational nature. During the alpha test of the application (semester 1, 2001, approximately 600 participants) 271 students completed the online evaluation, the vast majority (75%) indicating they accessed the Internet daily and that this was done from their home.

There was a range of evaluation questions relating to the content of the pre-laboratory work that students responded to, which allowed continued optomisation of the online resource. While the overall evaluation was very positive, it indicated where we should direct our focus to improve the online pre-laboratory work – there was a request for more extensive feedback to the quiz answers for example. We have been able to incorporate these modifications for the launch of the application to all of our first year students in 2002.

Our perspective

There has been a big gain in the useful laboratory time available to the students now that the tutors do not mark pre-laboratory work at the start of each session. Feedback from the tutors concerning this has also been very positive.

We are still experiencing some problems with the students incorrectly entering their identification number or laboratory details but these are generally easily sorted out. This online approach means that it is not possible for students to complete the pre-laboratory work while on the train travelling to their laboratory class however the requirement of a static environment is probably more conducive to learning!

Acknowledgements

The financial support of The School of Chemistry, The University of Sydney and IT Committee of The University of Sydney is gratefully acknowledged as an essential part of this project. Moreover the success of a project such as this is due, in large part, to the dedication, willing hard work and good humour of a team of people. Particular mention should be made of Jason Bayly and Lisa Hodgson for writing the software, Craig Barnes for composting the text and Don Radford for writing the quiz questions all of whom played a major role in the project.

Reference

George, A. V. (2001) Online Preparation for Laboratory Work. *CAL-laborate*, **7**, 11-15, [Online] Available: http://science.uniserve.edu.au/pubs/callab/vol7/george.html [2002, April 4].

Developing a project laboratory course in chemistry

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Introduction

During the redesign of the BSc degree structure at UNSW in 1998-1999, we set out to develop some third year chemistry courses which were not constrained by the conventional partitioning into 'organic', 'inorganic', 'analytical' and 'physical' chemistry designations. We also wished to provide all graduating students (in both three and four year degrees) with the opportunity to do project-based experimental work. Meanwhile, consultation with employer groups consistently highlighted team work, planning, organisational and communication skills as being highly desirable in graduates, but employers generally perceived science graduates to be deficient in some of these areas. We had previous experience of running problem-solving laboratories in an advanced analytical chemistry course and this came to serve as the pilot phase in the development of the new course. This paper describes the development of the project laboratory course in chemistry, its aims and outcomes, the feedback from students and how this influenced the further development of the course.

Course development

Pilot phase

The idea for a laboratory program based on problem-solving or project work initially emerged during a review of an advanced analytical chemistry course, taken by third year chemistry majors. These students had already taken a course in instrumental analysis and it was decided that an advanced course should not merely consist of more difficult set experiments. Instead, students would be presented with an analytical problem and would develop and implement an experimental strategy to solve it. The problems were presented as scenarios that might confront an analytical chemist working in a consulting or research laboratory.

This laboratory ran for two years during which time feedback from students was almost uniformly positive, with only one student expressing a preference for 'set practicals' over the problem-based approach. The consistent response was that the laboratories were more enjoyable while at the same time giving students insight into 'real' analytical chemistry.

Full course design

Developing a full course based on project work posed additional challenges over those experienced in the pilot analytical chemistry course. The scope was broadened to include all areas of chemistry and the course is open to students having a wide range of chemistry backgrounds, the only prerequisite being completion of at least one other third year chemistry course. The aims were (a) to make problem-solving and team work central to the course and (b) to provide the opportunity for students to develop skills in planning and experimental design as well as written and oral communication. Students are given as much autonomy as possible in running the projects, while staff are available for support and advice at all stages from planning through to reporting. The course is a 14 week course during which students carry out two 7-week projects, one in synthetic chemistry and one in physical/analytical chemistry.

The structure of a 7-week project is shown in Table 1. The group size is typically 4 students, although groups of 3 and 5 have been used. Students are given some choice in selection of projects and groups usually rearrange for the second half of the course. Several class meetings are held during the planning stages, to ensure that students are aware of the various issues involved. These include clearly defining the goals of the project, proposing specific experiments, estimating the feasibility of these experiments and carrying out risk assessments. Students are responsible for 'ordering' chemicals in advance from the laboratory staff and booking access to shared instrumentation. Good communication between group members and clear allocation of responsibilities on a week-by-week basis is therefore essential if progress is to be made.

Timing	Activities	Comments
Week 1 – induction	Groups formed; projects allocated; literature review and planning	A project consultant is available to assist groups in planning and laboratory set-up
Week 2 – experimental plan	Groups present a written plan and initial risk assessment	Experimental work begins once the plan and safety aspects have been approved
Weeks 3-6 – experiments	Experimental work for the project (open laboratory format; 6 hours laboratory work per week per student)	A progress report is presented in week 4
Week 7 – project report	All work must be completed by week 7	A written project report and seminars are presented

Table 1. Structure of a project module

Student feedback

Overall students have given very positive feedback although some minor fine-tuning continues. The major issue of concern to students is the group-work aspect of the course and how it might influence their assessment. A briefing is held in advance to explain the course structure and since the course is an elective, students with major concerns in this regard can opt out. While the assessment is mainly based on group reports, some individual assessment of seminar presentations and laboratory notebooks is included. Peer group assessment has also been introduced, to enable groups to report on the contributions of their members to the work of the project. In order to improve team work operation, a more formal induction into group work is being included in the induction phase of the course.

Students are highly motivated by projects which have a well-defined context and the most popular projects are those where the outcomes have some practical significance. Synthetic chemistry projects are more difficult to design to suit the 7-week period and some further refinement in this area is being undertaken. Examples of projects are available on request from the author.

Conclusions

The course has successfully met its major aims. Overall the course has proved beneficial to students going on to an honours year but has been equally valuable to students moving into the workplace with a three year degree.

Acknowledgements

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Teaching mathematical statistics

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Abstract: It is recognized that Statistics stands as an integral part of the basic training for citizens of many countries around the world. Although statistical skills are necessary in almost every field of the modern world (e.g. medicine, biology, business, finance, banking, engineering, ecology, etc.), many students continue to find such courses unappealing. At present, there is a growing need to convey the importance of teaching and learning of probability and statistics to students at all levels, particularly undergraduates. On this note, we discuss a process of developing a useful method of teaching mathematical statistics to undergraduates in order to improve their learning skills and understanding.

Introduction

Many teaching goals are shared and understood by almost all teachers in every area of teaching. For example, all teachers want their students:

- to understand certain underlying principles; and
- to improve a range of skills.

In addition to the above goals of teaching activities further questions of interest are:

- how to develop an interest (among students) of the subject? and
- how to encourage high quality learning?

Answers to the above questions relating to mathematical statistics are not easy to derive from traditional teaching methods. The main reason for this is that mathematical statistics is a sophisticated subject in which each branch requires a clear and broad knowledge of mathematics. The purpose of this article is to describe a process of developing a useful method of teaching mathematical statistics to first year undergraduates (with 2 Unit or less mathematics at their HSC) in order to improve their skills and understanding.

Some primary solutions

It is known that the first few weeks of a session are important for students, especially for first year students. Consequently, it is imperative that confidence and interest in the subject must be developed among students within these weeks using one or more of the following aspects:

1. showing the usefulness of this subject in their career;
2. showing the usefulness of this subject in the modern world; and
3. showing the relevance of modern techniques (i.e. computers).

Abstraction is another useful and essential tool to teach in any area of mathematical science as it focuses on key ideas which underline different phenomena and enables one to build his or her own strong foundation. However, abstraction leads to two main difficulties in teaching mathematical statistics. Firstly, the students have to master some basic results of mathematics before starting mathematical statistics. If a student falters without recovering then what follows may become incomprehensible. The student loses confidence and the benefit of subsequent teaching may become lost. Students will falter if the material is presented too quickly or if too much is assumed. Secondly, if the abstraction is not motivated or presented in context then the student loses intuition and interest. In Section 3, we provide some proposals in practical teaching in order to overcome these difficulties.

Teaching in practice

To overcome the first difficulty (confidence) in Section 2 is fairly easy and can be handled by any teacher in his or her own traditional way. However, the two difficulties under abstraction must be considered carefully as follows:

1. Provide written copies of detailed and reliable notes on basic mathematical results which need to develop the subject slowly and carefully. Also provide detailed notes to students so that the student can fall back on these if a lecture is not understood. These notes must provide a substitute and a better explanation of the material.
2. Teachers need to focus on specific concrete problems whose statements can be understood immediately, but the solutions of which depend on material developed during the course.

Flexible teaching and learning

The main part of our role as teachers is to develop the student's intuition by careful choice of pithy but accessible problems and examples and wherever possible to reinforce ideas with analogues and methods of visualizing information. One way of doing this in statistics is, begin each topic with a data set from a real study of current or historical interest to show the importance of the topic, with an emphasis on applications, then slowly proceed towards theoretical work. This has proven to motivate students. To improve the quality of teaching and learning, survey all courses at the end of each lecture (at least in the first few weeks) asking students about the pace and the level of the material. Take advantage of their responses to make decisions about how we might improve the standard of teaching and facilitate high quality learning in subsequent lectures.

References

Brewer, J. K. (1985) Behavioural Statistics textbooks - source of myths and misconcepts? *Journal of Educational Statistics*, **10**, 252-268.

Everitt, B. and Hay, D. (1992) Talking about statistics: A psychologist's guide to design and analysis. *Statistical Science*, **4**, 394-408.

Ramsden, P. (1992) *Learning to Teach in Higher Education*. London: Routledge.

Sowey, E. (1995) Teaching statistics: Making it memorable. *Journal of Statistics Education*, **3**(2).

Stockburger, D. (1996) *Introductory statistics: Concepts, models and applications*. [Online] Available: http://www.psychstat.smsu.edu/sbk00.htm.

Interactive lecturing using a classroom communication system

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Abstract: Large lecture classes are a dominant feature of many first year university courses. Is there a way to transform passive lectures into environments in which students are actively engaged in learning? Interactivity can be introduced into lectures through mini group quizzes, buzz sessions and a 'show-of-hands'. Although these strategies are successful they are not very effective in informing students about what and how their classmates think.

Current instructional technology based on information technology, enables instantaneous and unbiased feedback from students during a lecture. Such systems are called classroom communication systems (CCS). In this paper we discuss the implementation of such an interactive lecturing system. The effectiveness of the CCS is being evaluated by comparing the results of examination questions addressed by the CCS during the lecture course with those from examination questions that probe similar concepts but which have not been addressed by the CCS. The method by which this evaluation is being carried out is described.

Introduction

The use of a classroom communication system (CCS) in large lecture classes provides a powerful technique for giving instant feedback to the class. A question with options is displayed on an overhead projector. Each student selects an option by pressing a number on a keypad. The responses are collected by a receiver, processed by a central computer, and displayed to the class in the form of a histogram. They can also be displayed in other formats that depend on the type of interaction that the lecturer aims to achieve. The lecturer can promote interactivity by assigning a keypad per three students and requesting group responses. Displaying the collective responses to the whole class helps improve students' confidence because they become aware that a fraction of the class thinks similarly to them (Shapiro, 1997; Poulis et al., 1998). In this paper we describe a trial of a CCS in the School of Physics, The University of Sydney.

The CCS can be used in various ways. The selection made by each keypad is stored allowing the CCS to be used for summative assessment in large lecture classes (Burnstein and Lederman, 2001; Shapiro, 1997). An improvement in student learning has been demonstrated where data was collected for two years prior to, and two years with the use of CCS. The study was extended to another two years without the use of CCS (Poulis et al., 1998). We have chosen to design and use multiple-choice questions using phenomenographical analysis (Marton and Saljo, 1976) of student responses to selected discussion type questions from previous year's examinations. In this paper we describe the design of multiple-choice questions and how the questions will be used to test the effectiveness of CCS.

Hardware, software and use of CCS

We have used the lecture hall package of a CCS called Personal Response System (from *Better Education Inc*. http://www.bedu.com/). The system consists of 2 infra-red receivers and 50 hand held keypads. The receivers are connected to a computer that collects, analyses and stores the data, which can also be imported into *Excel*. The computer is connected to a LCD display unit. Information about the time remaining to answer the question and which keypads have registered a response are displayed as the computer counts down. A histogram of results is displayed when time allocated for answering the question expires. The question itself is displayed on a separate overhead projector.

The CCS is being used in first year physics lectures for the Fundamentals and Environmental units of study in medium size lecture theatres, which have a capacity of 180 students. One keypad per group of three students is used as part of the group discussion approach. As a trial run in 2002, the CCS is being used in lectures every fortnight.

Evaluation and effectiveness of CCS

The CCS is being evaluated using minute papers, focus groups and written questionnaires. In this section we provide a brief description of the effectiveness of CCS. A set of multiple-choice questions are being developed and implemented with the CCS. The questions are based on specially selected past years' examination papers and answering them involves the use of several concepts to form a short written explanation. Student responses from previous years have been categorised using phenomenography. The categories then form the basis of the options in the multiple-choice question. This allows for the use of ideas as perceived by students. Because the questions are complex in nature, two step multiple-choice questions are being designed. An added benefit of the two step question is that students are required to reflect on, and reuse a concept before answering the second part. This consolidates the learning that has occurred. The two step multiple-choice question is derived from categorising student responses to a 2000 examination question. The categories and the number of students in each category, for the 2000 student responses, have been obtained. Lecturers have been requested to set some examination questions in 2002 based on the concepts used in the questions chosen in this study. A phenomenographical analysis will be carried out on the 2002 student responses. A comparison of the 2000 and 2002 data will provide information on the differences, if any, between student understanding of relevant concepts, and the effectiveness of CCS in understanding these concepts.

Students are using the CCS with enthusiasm and lecturers have reported that the hardware and software are easy to use. In addition, lecturers have noted that the interactivity in lectures has increased with the use of CCS.

Conclusion

A classroom communication system is being successfully used in large lecture classes. Student response has been encouraging and staff have readily adapted to using this technology. Evaluations are being carried out to determine the impact, if any, of CCS on student learning. During this process we have identified the use of two step multiple-choice questions as a means of consolidating the learning of concepts.

References

Burnstein, R. A. and Lederman, L. M. (2001) Using wireless keypads in lecture classes. *The Physics Teacher*, **39**, 8-11.

Marton, F. and Saljo, R. (1976) On qualitative differences in learning: 1-outcome and process. *British Journal of Educational Psychology*, **46**, 4-11.

Poulis, J., Massen, C., Robens, E. and Gilbert, M. (1998) Physics lecturing with audience paced feedback. *American Journal of Physics*, **66**, 439-441.

Shapiro, J. A. (1997) Electronic student response found feasible in large science lecture hall. *Journal of Computer Science and Technology*, May, 408-412.

Learning to teach physics – Online

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Abstract: The University of Canberra Schools of Teacher Education and of Electronics and Telecommunications Engineering have established a new Graduate Certificate in Physics Education. The course has been designed to meet the needs of the NSW Department of Education and Training (DET) and provides an integrated combination of physics content knowledge, laboratory skills and pedagogic theory, specific to the teaching of physics, which will enable science educators to teach physics at secondary level to year 12 and take a leadership role at the school level in the planning and delivery of Preliminary and HSC Physics courses.

The course is to target established science teachers with science degrees and teaching qualifications. These teachers will be sourced from anywhere in NSW and consequently the course will be delivered online. All teachers taking the course are fully funded by the NSW DET. Enrolments for 2002 are 32 with the prospect of a similar number for 2003. Designing such a course is a significant responsibility, as it could influence how physics will be taught in over 60 schools in NSW in the immediate future.

In this poster we will discuss the intended objectives and content of the course, our philosophy behind the course content as well as the technicalities of how the course will be presented online.

Real and virtual experiential learning on the Mekong: Field schools, e-sims and cultural challenge

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Abstract: This poster describes two innovative and linked approaches to teaching the environmental geography of a region remote from students' normal experiential options. The first approach is field-based learning through Field Schools carried out over five weeks as a collaboration between Sydney University students and students in Vietnam, Laos and Thailand. The second approach is a structured role-playing web-based simulation exercise (e-sim) on Mekong Basin environmental management challenges, run over four weeks for students at three Australian universities from both social and physical science backgrounds (human and environmental geography; groundwater management and engineering). All 20 students who participate in the Field School also go on to join the approximately 150 students who are part of the e-sim.

Both the Field School and the e-sim have multiple objectives, including substantive learning about development and environmental challenges as experienced and dealt with by different social actors in the six countries of the Mekong Region and by Australian and other external interests in that region. Another significant objective is to give students experiential skills in dealing with cultural difference, particularly in the field of environmental and natural resource management. Two dimensions of culture are part of this process: the cultures of different societies and countries, and the discipline cultures of the social and natural sciences.

Teaching and learning contemporary physics concepts online

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Abstract: For about 15 years Kansas State University has offered a course called Contemporary Physics which targets secondary education and other science majors. The course is strongly activity based, and the students work through a series of explorations and applications to build an understanding of energy conservation, the particle and wave nature of electrons, the wave function and other quantum physics concepts. In order to make this course more accessible to under-

prepared physics teachers in Kansas we have adapted this course to an online format. We have made every effort to preserve the successful teaching and learning environment of the existing course in the online version by including computer-based and hands-on activities, interaction with fellow students and individual feedback. The first group of students has completed the online course and this poster will present some results of the evaluation on student learning and experiences using this delivery method.

Additional information is available at http://www.phys.ksu.edu/perg/.

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A web-based resource for radiation safety courses

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Abstract: CQU runs regular courses for intending Radiation Safety Officers from a variety of industry sectors. Participants have varying levels of prior knowledge to bring to the intensive three day program. To cater for those students whose prior knowledge of radiation physics is weak the print-based media for the course have been converted into a CD-ROM incorporating animations, worked examples, progress checks and self-assessment items. This allows the students who need extra study time on the basic physics concepts to cover as much as possible of the material before commencement of the course. The first course sessions can then concentrate on students' individual problems and the required program content. This approach also allows the student with strong prior learning to submit an assessment test and be awarded a partial course exemption.

Although the material selection is specifically for Radiation Safety training the CD-ROM has also been used in bridging courses, as reinforcement for first year students, and within our Engineering Technology Instrumentation program. The number of students who have used the CD-ROM is not statistically significant but student feedback on the material is very positive.

Just how different are they? Learning physics in the wake of the NSW HSC syllabus changeover

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Abstract: In February 2001 we began research into the different ways incoming first year students experience their studies in physics. We designed a survey instrument to measure the 2001 cohort of students' approaches to learning, their ideas about the nature of the subject, their perspectives on the learning environment at university and their performance on assessment.

Interrelations between these different factors form a broad picture of student learning and groups of students with distinct patterns of experience have been identified. In 2002 we are repeating this study with the aim of examining any qualitative or quantitative changes in these patterns of experience that coincide with the changeover to the new NSW Higher School Certificate syllabus. An understanding of our students' experiences will provide the necessary background to review our own tertiary physics courses and tune them to meet the needs of future students.

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