A PROBLEM-BASED LEARNING APPROACH TO INTRODUCTORY LOGIC

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ABSTRACT

This paper describes the restructuring of a second year logic course at Trinity College, Dublin. The course aims to develop student skills in the propositional and predicate calculi and to encourage students to exercise these skills in applications that arise in computer science and discrete mathematics. This paper details how the teaching methods used for this course were realigned with these aims. The restructured course is being delivered for the first time in 2002 and its outcomes will be reported on in detail at the Conference in July.

1 Introduction

It is claimed in [1] that teaching students about proof using formal proof methods is superior to teaching them using "semiformal" methods. The calculational predicate logic of the text *A Logical Approach to Discrete Math* [2] has been proposed as one possible method of achieving this. This text has been recommended for the introductory logic course 2ICT5 for the last four years. This is a second year undergraduate course taken by Information and Communications Technology students in Trinity College, Dublin.

The aims of the course are to develop student skills in the propositional and predicate calculi and to encourage students to exercise these skills in applications that arise in computer science and discrete mathematics. It was felt that these aims were not reflected in the method of course presentation; too much emphasis was placed on the technical theory involved, and too little on the application of the material.

It was noticeable in both lab classes and exams that students tended to avoid questions requiring the very skills that the course tries to promote. This paper reports on major developmental work done on the course to realign the teaching methods with the course aims. The students work in small groups on substantial problem sequences, supported by the lecturer and postgraduate assistants. The students themselves, guided by the problems, construct most of the course theory. However, they also attend plenary lectures where recent themes are pulled together and coming themes previewed. Each student's work for the semester is collected in a portfolio which will form part of the continuous assessment for the course. They will also be required to submit a number of assignments and sit the usual end-of-term examination.

Major developmental work was required to produce course materials to implement the proposed restructuring. It was necessary to produce a workbook of "terse" notes, sample questions with solutions, portfolio questions and assignments. The increased emphasis on problem-based learning and problem solving should create an atmosphere where students engage with the course in a more meaningful and appropriate way. The restructured course is being offered to students for the first time in the second semester of the 2001/2002 academic year.

2 Aims and Objectives

This project aims to address a problem with the delivery of the second year undergraduate course "An Introduction to Logic". This is a 12 week course, with three contact hours per student per week. It is based on *A Logical Approach to Discrete Math* by Gries and Schneider [2]. This book employs a novel approach to the teaching of logic, teaching students to view formal logic as a fundamental and pervasive tool and encouraging them to use it in many different applications. For this purpose the authors use an equational logic, a formalization which the author of this paper has not seen in any other logic text. This lack of reference texts that use equational logic reduces the inputs to student learning significantly and is one of the areas addressed by this project.

In previous years the course was taught using the traditional method of two expository lectures and one tutorial per student per week. Reflection on this structure, course evaluation questionnaires and informal discussions with a postgraduate student

who took the course during a previous academic year, have led to the conclusion that the emphasis of the course presentation needs to focus more on the application of the material. The existing emphasis of the course led students to take a surface approach to learning, and this was reflected in their preference for the more theoretical examination questions. Only 86% of students attempted the examination question based on the application of the material involved, while 100% of students attempted the purely theoretical examination question. Moreover, students scored twice as well on the theoretical question then on the application based question.

3 Implementation

The project is presently being implemented as part of the second year mathematics strand of the Information and Communications Technology degree program. A detailed description of each of the main components of the project is given below.

3.1 Course Delivery

Each one hour class involves a mixture of problem-based learning, problem solving and discussion, complemented by a small amount of blackboard teaching. Each week the students are given a sequence of problems to work through in class. They are encouraged to work on these problems with other students and to interact freely with the lecturer and postgraduate assistants.

3.2 Assessment

All students are required to keep their solutions to the class problems in a portfolio. The semester is split into two six weeks terms and the portfolio is submitted for assessment at the start of the second term. This forms half the overall continuous assessment mark for the course. Any portfolio problems which are not finished in class must be completed in the students own study time.

As well as the portfolio problems, the students are given two assignments to complete. These will generally contain questions similar to those done in class. These must be completed within a week and handed in for marking. Each week the students also receive a selection of extra problems, designed to be more challenging than the portfolio and assignment problems. The stronger students in the class are encouraged to attempt these problems.

3.3 Plenary Lectures

During the semester a number of plenary lectures will be given, these pull together the themes of the previous weeks and help to chart the way through the course.

A postdoctoral assistant was employed to assist in the constructive alignment of the course materials with the desired learning outcomes. The assistant's main task was to produce a workbook to be used to engage students in learning activities that are likely to achieve the desired learning outcome of increased skill in the application of the material being covered.

It is expected that the course restructuring will lead to students taking a deeper approach to their study of the course material. It is envisaged that this will have been facilitated by use of the course workbook and materials. In order to assess the impact of the course on student learning, two class surveys will be conducted at equally spaced intervals during the course. The feedback obtained from these will be analysed to evaluate the outcomes of the course, and to further refine the course for delivery in subsequent years.

4 Project Outcomes

The revised course objectives, along with the new methods of teaching and assessment, should create a learning environment that encourages students to engage more fully with the course. In previous years the level of understanding reached by many students taking the course can be described as multistructural (using the SOLO taxonomy, described in [3]): Students view the course as a "disorganized collection of items" and are unable to apply the concepts to problems of a similar format to those encountered during the course. Using the restructured course outlined above; students should develop a deeper understanding of how the concepts form an integral part of the theory of logic, and then be able to relate the concepts to the assigned problems.

The less academically committed students within the class should benefit from this project as the more active teaching methods employed should require such students to view the material at a higher level – relating, applying and possibly theorising about what is involved.

5 Evaluation

The main aim of the restructuring outlined above is to encourage students to engage more fully with the material to be covered. Both formative and summative assessment will be used to determine the success of the project in terms of learning strategies adopted by the students and examination results achieved.

Examination performance and survey results obtained during the project implementation in the 2001/2002 academic year will be compared and contrasted with with those obtained during previous years of the course. [4] outlines the link between attitudes toward mathematics and performance in undergraduate engineering mathematics courses, so this study will look for the existence of a similar link in undergraduate computer science courses.

Specific details of how the learning methods adopted by the students will be assessed are provided below:

A course diary will be kept by the lecturer. This will be filled in after each contact session, and will include brief descriptions of the material covered, as well as reflections on the teaching methods used. The students' level of interest, quality of understanding and the extent of retention of key points will also be noted. Any general feedback from the students will also be included in the diary.

A structured group feedback session will take place after six weeks of the course. This will be based on the methods outlined in [5] and involved asking each class member write down their answers to a number of questions, including:

1. What was the BEST feature of the course for you?
2. What was the WORST feature of the course for you?
3. What ways do you think the course could be IMPROVED?

The students will be asked to discuss their responses in groups of four, and to record points on which they are agreed. These comments will then be collated by the lecturer in front of the whole class. The feedback obtained will be used to evaluate student learning methods and to determine any necessary changes to the course structure. The lecturer will report to the class on how the information obtained will be used.

The postgraduate assistants will also be used to help determine the approach the students adopt to the course. The assistants will be able to assess the students grasp of problems they are tackling by asking questions on how they intend to approach problems. A comprehensive questionnaire that includes both numerical gradings and open-ended questions will be given to students during the last week of the course. This will assess a number of aspects of the course, including the effectiveness of the project in terms of student learning. The final examination will also be used to assist in the evaluation of the course. A study of types of questions tackled, as well as analysis of the final marks awarded, should provide evidence of the learning approaches adopted by the students.

6 Preliminary Evaluation

Preliminary results from an evaluation of the first six weeks of the course are only available at the time of writing. This is due to the fact that this course is being presented for the first time in 2002. This section includes both qualitative results obtained for the group feedback session outlined above and quantitative results from the annual Foundation Scholarship examination. Foundation Scholars of Trinity College are elected each year based on the results of these examinations. As these examinations are not compulsory, it is usually only the stronger students that choose to sit them.

6.1 Qualitative Results

Students who sat the course in previous years made the following observations:

- "I enjoyed reasoning about problems in English, although it was difficult."
- "I was recently asked for help by a second year student. I looked at the question and hadn't the faintest idea how to do it. Perhaps I learned a certain frame of mind for approaching problems, but not much else."
- "The tutorials should be made shorter so that it is possible to finish them within the time given."

Students sitting the course during the current academic year made the following observations:

- "I think it is a good idea to encourage the practice of the logical methods involved in order to help us understand the course better ."

- " The tutorials are very helpful but there is too much work involved in the portfolios."
- " The amount of formulae can seem overwhelming, but I'm beginning to understand how they all fit together."

6.2 Quantitative Results

In the Foundation Scholarship examination of 2002 it was noted that all students attempted the "applied" examination question, compared to 60% of students in 2001. The observed significance level associated with this difference is 0.01% and so we conclude that there is a significant difference in the proportion of students attempting the applied question in 2002 compared to those who attempted the applied question in 2001.

The difference between the average examination scores on this question were also compared. The null hypothesis used was that the average scores obtained in 2001 and 2002 were the same; while the alternate hypothesis was that the 2002 average result was significantly higher than that from 2001. It was concluded that the two values differ significantly as the observed significance level for the test was 0.8%. We may thus conclude that current students did better on the applied question on the Foundation Scholarship examination than those in 2001.

Students were surveyed in order to ascertain how they viewed the course objectives. They were asked to indicate if they felt the objective given related to the second year logic course. The table below give a list of objectives and the percentage of students who viewed them as being core objectives of the course. The observed significance levels given relate to the difference between the percentages shown in each row in the table.

Objective	2002	2001	Observed significance level
Manipulating Boolean Expressions	85.4%	78.4%	24.2%
Applying propositional calculus	74%	64%	20%
Translation of English statements into Boolean Expressions	65.4%	87.6%	1.79%
Developing different methods of proof	63.6%	63%	48%
Reasoning about variables other than Boolean ones	54.54%	67.6%	14.69%

Table 1: Student ratings of core course objectives

There is a significant difference in the perceived importance of translating English statements into Boolean expressions, with past students viewing this as the primary objective of the course. The data obtained from the current students suggest that they believe the course is focused on the manipulation of Boolean expressions. It should be noted that current students have not yet completed the course and that their impression of the course objectives may change over the final six weeks of the course.

These preliminary results suggest that the realignment of the course materials with the stated objectives is achieving the required results. More detailed data and analysis will be required to prove this is the case.

7 Summary

In this paper we have detailed a new teaching initiative being introduced to a second year logic course at Trinity College, Dublin. Preliminary results indicate that students are more willing to attempt applied examination questions and view the course objectives as being more than just the translation of English statements into Boolean expressions.

A full analysis of the impact of these initiatives on student learning will be completed by June 2002. A detailed report on the outcomes, including a full analysis of the data obtained along with details of problems encountered will be given at the Conference in July.

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