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Problem-based approach in teaching advanced robotics

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Abstract

Robotics is an elective subject offered in the three Departments of Electrical and Computer Engineering, Mechanical Engineering and Computer Science at both undergraduate and postgraduate levels. As Robotics is dealt with in a similar way in each department, the trend has been to offer a common subject and share the teaching load. Robotics is a multi-disciplinary subject covering various topics in mathematics, mechanics, control, instrumentation and sensors. The students, however, have distinctly different academic backgrounds. The combinations of these factors, ie the diversity of the students and the nature of the subject, create a teaching environment which is quite challenging but has great potential for innovation in teaching and learning. In this article a teaching approach specifically tailored to meet the challenges of this subject is described. This is basically a problem-based approach which attempts to achieve the essential characteristics of "cognitive apprenticeship" as outlined by Wilson and Cole. The important components of the teaching innovation will be highlighted, and outcomes measured by teaching diagnostic surveys conducted in 1994 and 1995 will be reported.

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Problem-based Approach in Teaching Advanced Robotics

Fazel Naghdy

Introduction

Robotics is an elective subject offered in the three Departments of Electrical and Computer Engineering, Mechanical Engineering and Computer Science at both undergraduate and postgraduate levels. As Robotics is dealt with in a similar way in each department, the trend has been to offer a common subject and share the teaching load. Robotics is a multi-disciplinary subject covering various topics in mathematics, mechanics, control, instrumentation and sensors. The students, however, have distinctly different academic backgrounds. The combinations of these factors, ie the diversity of the students and the nature of the subject, create a teaching environment which is quite challenging but has great potential for innovation in teaching and learning.

In this article a teaching approach specifically tailored to meet the challenges of this subject is described. This is basically a problem-based approach which attempts to achieve the essential characteristics of "cognitive apprenticeship" as outlined by Wilson and Cole[1]. The important components of the teaching innovation will be highlighted, and outcomes measured by teaching diagnostic surveys conducted in 1994 and 1995 will be reported.

Background

Advanced Robotics is offered as a 4 credit point subject to undergraduate students. Postgraduate students do 6 credit points and are required to do an equivalent of 2 credit points extra work. The subject allows for 3 hours contact time per week for 14 weeks. The main aim of the subject is to provide the students with an opportunity to become familiar with the basic principles and concepts of robotics and its application in modern manufacturing systems. The objectives of the subject are that students should be able to:

i) design a robot manipulator to perform a specific task;

ii) plan the trajectory of the motion of the robot;

iii) design the internal and external sensors required for the robot; and

iv) plan the integration of the robot in a production line.

As mentioned before, the teaching load is shared by the three departments. I teach 50% of the subject, aiming to achieve objectives (i) and (ii).

After teaching the subject for a couple of years, I became aware that the students all had different interests, expertise and expectations. Hence relying on conventional lectures was not an ideal solution as it did not satisfy the overall requirements of the class. I was particularly concerned with the passive reaction of many students to the lectures, their weakness in solving the tutorial problems given to them and their inability to follow the lectures from one week to the next.

I examined ways to enhance the teaching and learning processes in this subject. After some reflection and searching the problems became more clear. A model which assisted me to develop a new approach was the "cognitive apprenticeship" model described in the instructional design literature. The model describes the relationship between the master (lecturer/tutor) and his/her apprentices (students). The term apprenticeship also calls to mind the notion of "hands on" learning which not only includes learning the theory but developing the skills needed to utilise the theory.

An apprenticeship therefore implies a transfer of knowledge to the apprentices about the processes involved and developing required skills in the students. The components of the "cognitive apprenticeship" model for teaching are:

Content - includes not only the conceptual, procedural and factual knowledge but also the heuristic knowledge such as tricks of the trade and hints.

Sequencing - develop instruction from the simple to the complex and from general rules to specific ones.

Situated learning - make learning relevant to the real world.

Modelling and explaining - describe the dynamics of the unfolding process.

Coaching - observe the progress of the students and provide feedback and helpful hints.

Articulation - encourage students to think and make decisions based on the acquired knowledge towards achieving an objective.

Reflection - encourage students to reflect on their work and analyse the results.

Exploration - enable students to consider various strategies in achieving an objective.

The Cognitive Apprenticeship model lends itself the best to a problem-based learning approach. Overall, I found this paradigm ideal to structure the teaching processes of the robotics subject.

Implementing a problem-based approach to learning

Initially I set the following objectives to introduce changes in the teaching and learning processes of the subject:

i) to create an active, inspiring and dynamic environment for learning within and without the classroom.

ii) to increase significantly the overall absorption of the taught materials by the students during the lecture time.

iii) to stimulate the students to think and reflect on the taught materials.

iv) to increase the appreciation of the practical value of the taught materials by the students.

In pursuit of these objectives and in line with the Cognitive Apprenticeship approach, I introduced the following major changes:

Reduced time in lectures

The length of the standard lecture was reduced from 2 hours to 1 hour per week. Lectures were mainly to introduce the topic, highlight its important aspects and illustrate its implications through examples. The format and style of delivery have evolved continuously. Employment of graphics, colour and animation using the Powerpoint software package would appear to have enhanced significantly the students' absorption of the lecture content. A copy of the slides was left in the reserve collection of the library and recently all the slides became available on the Department's WWW Home Page in the same style and quality presented in the classroom.

Introduction of an interactive workshop

The second hour previously spent on lectures was dedicated to a dynamic process between the lecturer and students in a workshop format. In this perod, the students were challenged by a series of problems on the topic just taught. The students were encouraged to work in small groups and continuously interact with each other and with the lecturer. They were progressively given hints and tips on how to tackle a specific problem to stimulate and encourage them to think about the problem and work on it. Various groups were then asked to present their solutions on the board and others were invited to comment on these solutions. Finally a discussion was held on the suitability or validity of a solution. Some new materials on the topic were also built into the workshops. Students were guided in the workshop to discover these concepts and apply them to a problem.

Remodelling of tutorials around a project

The last hour of contact time each week was used to work on a project. At the beginning of the session the students were divided into groups of 4 and were given a project to work on during the whole 7 weeks of this part of the subject. A typical project used is illustrated in Figure 1. The students were asked to design a robot to pick a nut from the nut magazine and tighten it on the bolts located on the horizontal plane. This problem has no unique solution and the design of the robot is directly proportional to how much a student has understood the underlying concepts and theory. The nature of the solution can also vary with the background of the students and their academic strength. For the project, the

students were asked to address various issues in the design of the robot. At the same time, the project was fully integrated into the lectures and workshops. Hence with each lecture the students could tackle further aspects of the design of the robot. This provided strong motivation for the students to pay full attention to the lectures and workshops to learn about the methods they needed to apply in their project. At the end of the session, each student wrote a report on the work carried out for the project. Each group was also asked to present their work to the rest of the class. The dynamics and enthusiasm generated as a result of this project have been very impressive.

Evaluation

The relationship between the components of the Cognitive Apprenticeship model and the approach I employed to teach Robotics is illustrated in Figure 2. It is clear that all aspects of this approach have been strongly supported by the introduced method.

The method has proved very successful in creating a dynamic learning environment, making the subject tangible for the students, increasing their enthusiasm for the subject and motivating them to work. Evidence is provided by the anecdotal comments made by the students during session, significant increases in the number of students electing to do this subject in the final year, and the results of the diagnostic surveys carried out by Academic Development Services.

In the Department of Electrical and Computer Engineering, a survey is carried out every year of third year students to get an estimate of the number who will do a particular elective. In 1995, a year after the introduction of the new method, the number of preferences for Robotics increased by 4 times compared to the previous year, with an increase of 12 to 42.

The results of the diagnostic surveys conducted for the 1994 and 1995 offerings of the subject are illustrated in Figures 3 - 10. These results clearly demonstrate that most students agreed that:

- The workshop and project increased the understanding and appreciation of the student for the subject.
- Working in groups enhanced the learning process.
- The new approach produced a satisfactory level of interaction in the classroom.
- The problem-based approach increased the degree of the assimilation of the theory.
- The project assisted the students to improve their skills in design.
- The project created skills in the students to work in a group towards a common goal.

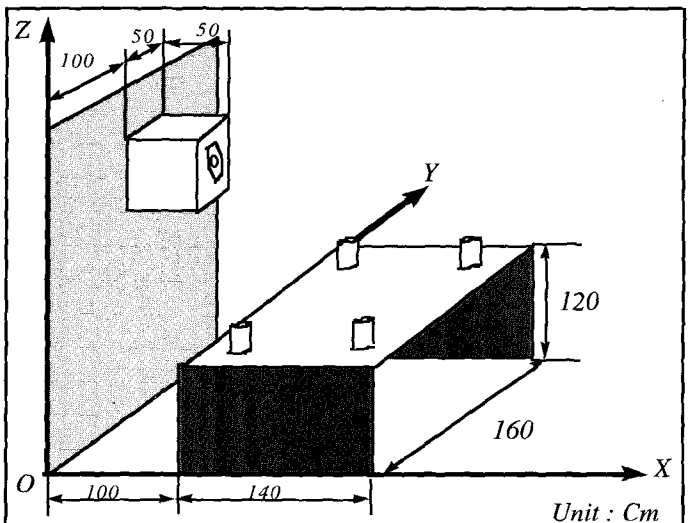


Fig 1. The robotics project

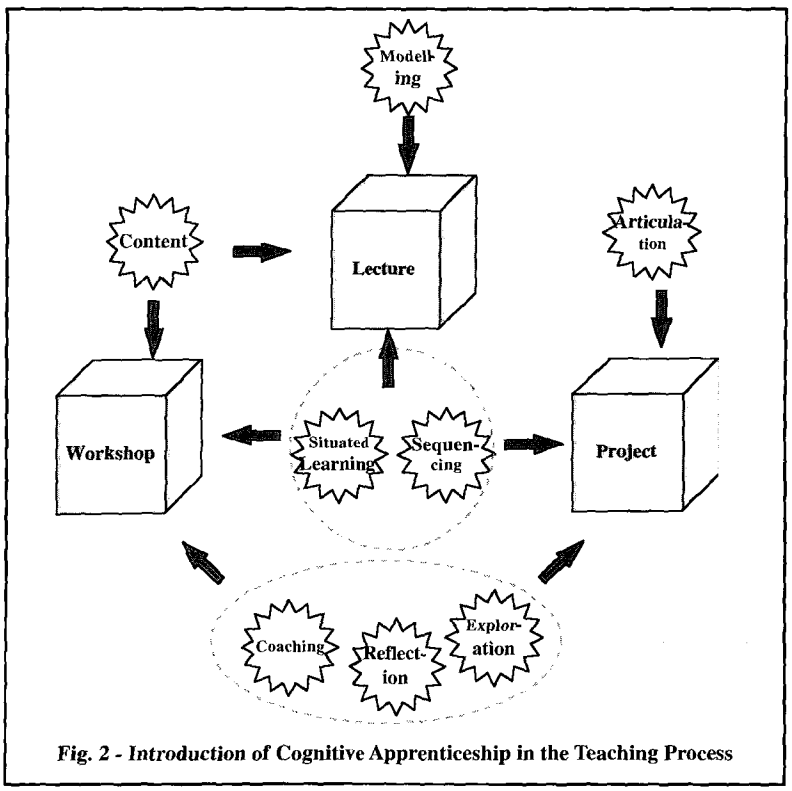


Fig. 2 - Introduction of Cognitive Apprenticeship in the Teaching Process

Figure 3 - Response to comment: Workshops in this subject have improved my understanding/appreciation of the subject

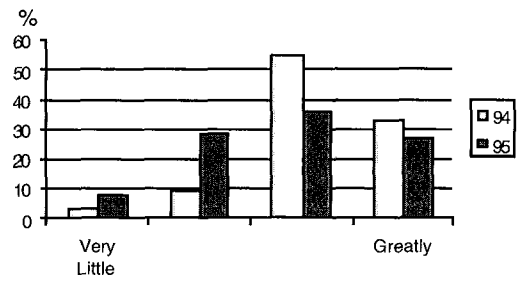


Figure 4 - Working in problem-solving groups in workshops assisted my learning

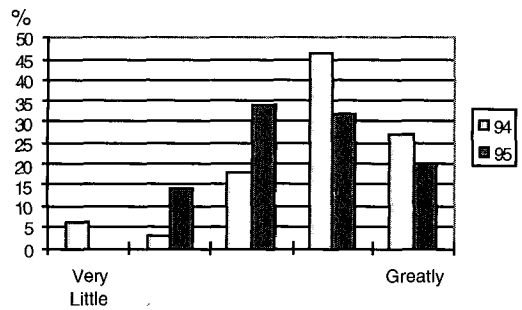


Fig 5. Compared to tutorials in other subjects workshops in this subject have helped my understanding

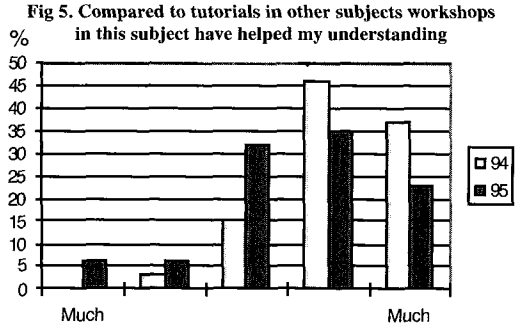


Figure 6 - The amount of class time for questions and discussion with the lecturer has been . . .

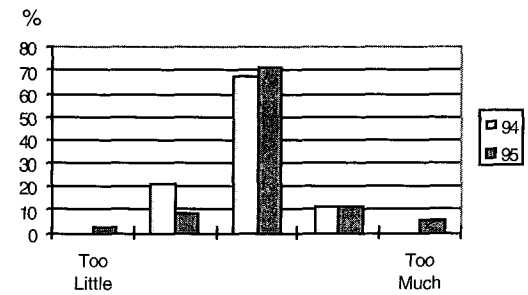


Figure 7- Doing the project has improved my understanding of lecture material . . .

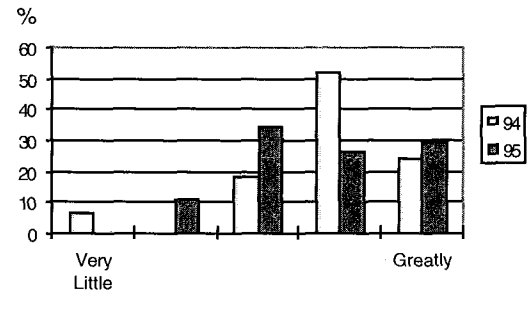


Figure 8 - As the result of doing the project my confidence in my ability to do design as a professional engineer has . . .

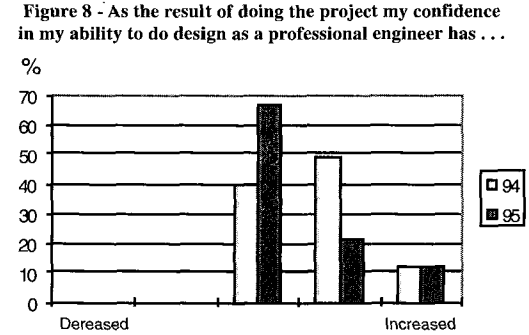
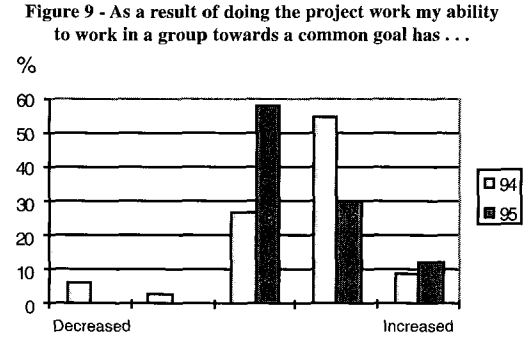


Figure 9 - As a result of doing the project work my ability to work in a group towards a common goal has . . .



Conclusion

The experience gained through the development and introduction of this method of teaching has been quite exciting and stimulating for me as the lecturer of the subject. It has also increased my confidence for further innovation and has produced clear positive educational outcomes for the students. There is good evidence indicating that the approach has contributed significantly towards enhancing the teaching and learning processes.

[1] *Wilson B, Cole P, "A review of cognitive teaching models", Educational Technology Research and Development, Vol 39 No 4, pp 47-64, 1991*