ALMOST A DECADE OF COGNITIVE SCIENCE AT SHEFFIELD

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Abstract

Sheffield was one of the first UK universities to introduce an undergraduate degree in Cognitive Science with an initial intake of students in 1990. The authors have been involved with teaching, admininistering, and developing the degree throughout the 1990s and most recently in overseeing its transformation into a degree entitled "Psychology and Cognitive Science". This paper provides a case-study of our experience in developing and co-ordinating Cognitive Science teaching at Sheffield. We review some of the particular problems we have faced, assess our varied attempts at solving them, and identify some unresolved issues which are likely to be faced by anyone seeking to provide training in Cognitive Science at an undergraduate level.

1 Introduction

The problems that arise in teaching Cognitive Science to undergraduates have previously received attention at a 1993 workshop for the National Science Foundation, and at two workshops for the Annual Conference of the Cognitive Science Society (in 1994 and again in 1998). Summaries of two of these meetings are available on the Internet (Stillings 1993; Kolodner, 1994). Although primarily concerned with teaching Cognitive Science in the US, these reports make reassuring reading for UK-based organisers of Cognitive Science degrees—there seems to be considerable universality in the experience of trying to co-ordinate an undergraduate degree in our field! Rather than reiterating many of the interesting points made in these reports, this paper aims to provide a case-study of our own experience in developing and co-ordinating Cognitive Science teaching at the University of Sheffield, UK. We will review some of the particular problems we have faced, try to assess our varied attempts at solving them, and identify some of the unresolved issues we are still struggling with today.

Sheffield was one of the first UK universities to introduce an undergraduate degree in Cognitive Science with an initial intake of students in 1990. The authors have been involved with teaching, administering, and developing this degree throughout the 1990s and most recently in overseeing its transformation into a degree entitled "Psychology and Cognitive Science". Some background on the development of the degree will explain how we got to where we are today.

2 The Original Cognitive Science Degree at Sheffield

Several objectives motivated the introduction of our original single honours degree in Cognitive Science:

(i) To give students a multi-disciplinary training in the different strands that contribute to Cognitive Science.

(ii) To educate students in the required methodological skills to tackle interesting undergraduate projects in Cognitive Science, and to graduate with the skills to undertake post-graduate research in Cognitive Science.

(iii) To allow students to discover where there own strengths and interests lie and then encourage them to develop expertise in those particular areas.

(iv) To teach subjects closer to the research activities of staff many of whom have strong Cognitive Science interests.

To address the first objective, inter-disciplinarity, our degree began life as a three-way partnership between the departments of Psychology, Computer Science, and Control Engineering. In the first two years of the degree, students were expected to gain a solid grounding in the cognitive and biological areas of psychology; computing and AI; and control theory and robotics. Students also had the option to take courses in the department of Philosophy. Methods courses (objective ii) included experimental and statistical psychology, computer programming and software design, and applied mathematics.

To allow students to direct their studies toward target areas (objective iii), the final year included a research project under the supervision of a member of staff, and optional advanced courses in topics of their own choosing. The degree was initially conceived as having very limited specific teaching in Cognitive Science (there was just one full-time post attached to the introduction of the course). However, in line with objective (iv) it was intended that final year students would have the skills to carry out undergraduate projects in particular areas of staff interest, and it was hoped that the best undergraduates could be encourage to stay on for postgraduate training in Sheffield.

This original degree has seen a number of important changes. First, as a three-way collaboration the degree lasted for only one year! During this time it was decided that the involvement of three departments made the administration of the course too cumbersome. Perhaps more importantly, however, it was felt that the courses on control and robotics taught in Engineering, although in principle concerned with relevant material, in practice were failing to engage or interest our students. This is, of course, symptomatic of the wider problem (discussed by Stillings, 1993), of how to finesse relevant interdisciplinary training for Cognitive Science undergraduates from courses designed to satisfy the teaching objectives of other fields. We have struggled with this problem in various guises throughout the time we have been teaching cognitive science.

As a more manageable partnership between Psychology and Computer Science the Cognitive Science degree has lasted for nearly a decade (the final students from this degree will graduate in 2001). Further changes during this time have been aimed at (i) narrowing down the core of the degree to provide more student choice, (ii) introducing specific Cognitive Science courses intended to provide a focus for the degree, and (iii) reducing the amounts of compulsory methods training. We briefly consider each of these issues below.

Core material

The problem of defining the core subject matter of Cognitive Science, has concerned previous workshops on teaching this subject to undergraduates (see Stillings 1993, Kolodner 1994), However, as yet, no specific proposals as to what should count as core have been made. There is consensus, however, in past workshop reports, that what distinguishes Cognitive Science from other approaches in the 'sciences of mind' is a computational or information processing perspective. This paradigm has confronted, and adapted to, various challenges over past decades. So, for instance, in response to the resurgence of connectionism in the 1980s, most degrees now recognise neural networks as a core topic, and regard various forms of distributed computation as fitting under the information processing umbrella. In the 1990s, however, there has been a new(ish), and more radical, challenge to the computational view coming from dynamical systems and autonomous robotics research. This work has asserted a dynamical rather computational understanding of cognition (see, for instance, Port and Van Gelder, 1995), and has questioned the significance for understanding human cognition of such core concepts as representation (distributed or otherwise), symbols (or sub-symbols), and computation itself. With the current level of turmoil in the field of Cognitive Science, the problem of designing a core curriculum has become even more difficult. The danger of introducing these alternative paradigms too early in a degree program is that it could encourage students to dismiss the standard computational approach to readily. On the other hand, if we do not provide appropriate coverage of these important debates within Cognitive Science, we could do our students and our subject a disservice, by failing to portray the current 'state of the art'.

The lack of consensus about what constitutes core Cognitive Science provides considerable freedom in designing an Undergraduate degree. At Sheffield we have chosen to play to our strengths and teach to those areas where we have most expertise. This has meant a Cognitive Science degree that emphasises topics such as connectionism, and computational approaches to vision and neuroscience, with less stress on traditional topics such as classical AI or linguistics. The emphasis in the first two years is on a fairly standard computational/ connectionist understanding of mind, while the dynamical/ computational debate is given some detailed consideration in a final year course.

As an interdisciplinary field, graduates in Cognitive Science should be expected to have some basic training in a number of contributing areas. The core of our degree has emphasised training in Psychology and Computer Science with some introduction to Philosophy. Professional accreditation is, of course, an issue for Cognitive Science graduates who may wish to enter careers in the more traditional fields (this is not helped by the lack of specific jobs for qualified Cognitive Scientists!). Our graduates are able to gain graduate membership of the British Psychological Society, although to get full graduate registration (allowing training as a clinical, educational, or occupational psychologist) students are required to take further optional courses in Psychology. Accreditation to the British Computing Society has not been an option for our students although this may be a less rigid bar to obtaining work in the computing industry.

Specific courses for Cognitive Science

Early on in the development of the degree we recognised the requirement for specific courses in Cognitive Science. There are several reasons for this. First, faced with an array of disparate modules in Psychology, Computing, and other disciplines, students need some teaching that integrates across these areas and demonstrates how they are related. Without this integration, students may want to migrate into the component discipline they find most appealing (indeed, despite our best efforts we still have several students in each intake moving into one or other of the parent disciplines). Second, specific courses can teach material in a way that makes it more relevant and accessible to our students, for instance, focusing on the use of neural networks for cognitive or brain modelling rather than on their use as function approximators in neural engineering. In practice, specific courses for Cognitive Science have been provided for our degree in the department of Psychology rather than in the department of Computer Science (this situation arose for various reasons including the generally lower teaching loads in Psychology). One unintended consequence of this imbalance, however, is that many students tended to see themselves as 'home' students of Psychology rather than being evenly based between the two departments—organising a degree with two home departments can be a difficult balancing act.

Methods training

When the degree was first established, our aim was to train students in a wide range of methodological skills in psychology, computing, and mathematics. In practice, we have found methods training to be one of the most problematic areas of the degree. The acquisition of programming skills has always proved difficult for a minority of our students and has lead to a significant number leaving the course (generally in the first year). To counteract this problem we have, over several years, reduced the amount of core training in computing methods. The question of whether Cognitive Science students should be trained in software design skills in addition to basic programming has also been a subject of some contention. This issue highlights a problem of teaching a degree which, to some extent, is like a dual honours, but in other ways is trying to target a specific mix of interdisciplinary skills (i.e. those required for computational modelling). Software design is clearly an important subject for students who go on to further training or employment in computing, however, it seems only tangentially related to the core subject matter of Cognitive Science (whatever that may be!). After much deliberation this subject was finally dropped from the core curriculum in 1997 to make way for (what was felt to be) more directly relevant material. Mathematics training has been another bugbear. Having, at various times, placed our students on applied mathematics courses taught in the context of other disciplines, we have found that the only truly satisfactory way to obtain the maths training we want is to provide a maths primer tailored to our students.

3 A Change of Tack—The New Degree in Psychology & Cognitive Science

By 1997 changes in personnel in the Department of Computer Science had resulted in an increase in staff with an interest in Artificial Intelligence. This led to the proposal of a new degree in "Artificial Intelligence and Computing Science". With respect to the existing degree in Cognitive Science, it was then agreed that there should be a 'parting of the ways', with Psychology introducing our own degree in "Psychology and Cognitive Science". The rationale for this change was the perception that within past cohorts of Cognitive Science students, we had often seen two different 'species', those for whom AI/Computing was a natural habitat and those whose bias was towards Psychology/ Computational modelling. Under the modular system at Sheffield both new degrees could take advantage of relevant modules taught in the other department without requiring joint administration. A third reason for the change (from the specific perspective of Psychology) was the problem of recruiting good students to the Cognitive Science degree. Although the Cognitive Science course had always filled its quota, this had never been entirely straightforward. In contrast, the Psychology single honours degree has always been heavily over-subscribed. It was hoped that by increasing the psychology content of the degree (and by including 'psychology' in the title) more good students would be attracted to apply. It is probably fair to say that there was also some relief, in both departments, at the prospect of being able to run their own degrees without needing to adopt compromises required to satisfy the other participant.

A summary of the new degree in Psychology and Cognitive Science, which has been phased in gradually from 1997-98 onwards, is given in the appendix. Several features of the degree deserve mention, although it is too early to judge whether the changes we have made have all been for the better. First, we have recognised that many of our students want the possibility of a professional qualification in Psychology, so we have made the path to full membership of the British Psychological So-

ciety easier to follow. Second, we have reduced to a minimum the amount of required methods training in the first year (though, of course, students are encouraged to take additional methods courses as options). Programming and mathematics methods (other than statistics) will now be taught only in the second year in a module that will be more directly linked to final year projects in computational modelling. Finally, we have lessened our emphasis on subjects such as neural networks and computer vision which required substantial technical training. Instead, we are providing broader courses in cognitive modelling that use pre-built computer simulations as the primary vehicle for lab teaching (a downside of this approach is that modules of this sort require a great deal of preparation). Technical courses, in various topics, are still available as options for students who want advanced training in methods.

One of our goals in reducing the technical content of Cognitive Science modules, is to encourage more students from other degrees (particularly straight Psychology) to take these courses. This should help to raise general awareness of the subject within the University (possibly attracting good students to the degree by internal transfer), and will also create a more economically-viable base for the specific teaching we provide for this small-cohort degree (about 17 students p.a.).

Where are we trying to get to?

Why have we taken this route in redesigning our degree? An analogy might help to illustrate our current position:

> *A traveller passing through Limerick asks one of the locals how to get to Dublin. His reply "Ah, my friend, so its Dublin you're wanting—well I wouldn't start from here if I were you".*

Essentially, having started out for Dublin (our notion of the technically sophisticated Cognitive Science degree), and having walked into several bogs, we are now adopting the more modest goal of exploring the gentler countryside around Limerick (where we are in Psychology) though tending toward the Dublin side. In other words, our new degree tries to give students some education in Cognitive Science while providing a solid foundation in a more traditional discipline and exploiting our particular strengths in teaching both Psychology and Cognitive Modelling. Admittedly, we have stopped short of our original goal (objective ii), to produce fully-fledged Cognitive Science researchers, but we hope to produce graduates with some basic skills, and enough knowledge and sophistication, to succeed on the right type of post-graduate training program.

4 Unresolved issues

Our current position reflects a number of hard choices that we have had to make. Our continuing efforts to improve and modify the course are motivated by a number of key issues which are summarised in the following questions, and which also serve as our conclusion.

What is Cognitive Science?

There is a lack of consensus both about scope of the term 'Cognitive Science' and also about its core subject matter. Currently course designers are left to decide this question themselves, but our collective answers, nationally and internationally, could influence the future shape of our subject.

How Technical?

Research in Cognitive Science often demands a high-level of understanding of computing and applied mathematics. Although the subject matter of Cognitive Science is interesting to many undergraduates, the reality of learning about Cognitive Science can seem very technical and 'hard'. Some of the questions we need to answer are: To what level do we wish to train graduates in the technical skills required to do Cognitive Science research? How can we strike a balance in teaching the subject between the 'gee-whizzery' of demonstrations (e.g. neural nets that learn to talk) and the hard grind of understanding the underlying machinery?

How can we sell Cognitive Science?

We have always found it more difficult to recruit school leavers to our Cognitive Science degree than to our undergraduate degrees in Psychology. This problem has been stubbornly resistant to several attempts to improve our promotional material and advertising. A central difficulty, we believe, is that the term "Cognitive Science" is too unfamiliar to our target audience of sixth formers. A second problem may be the lack of any perceived link between Cognitive Science training and specific vocations or forms of employment outside the research arena. Questions that need to be answered include: How do we raise awareness of Cognitive Science in schools and amongst potential employers? Is there any co-ordinated action that could be carried out across the UK Cognitive Science community which could help to raise the profile of our field?

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Appendix: the Degree in Psychology and Cognitive Science at Sheffield

In each year students take a total of twelve *half-modules* (or *six full-modules*) spread over two semesters. Except where indicated all the modules listed below are half-modules. Asterisks indicates modules provided primarily as support for this degree.

First Year

Discovering psychology (full-module)
Discovering cognitive science*
Psychology and everyday life (full-module)
Methods and reasoning for psychologists
Introduction to philosophy (half or full-module)

Four or five further level one half-modules

Second Year

Language, memory, and thought
Perception and learning
Neuroscience and behaviour
Psychological methods I
Thinking and study skills for psychologists
Models of mind*
Psychological methods III: computational models*

Three further approved half-modules in psychology, artificial intelligence, or philosophy

Two unrestricted half-modules

Third Year

Research project (three half-modules)
Co-operative models of mind*
Computational neuroscience*
Visual perception

Six further approved half modules in psychology, artificial intelligence, or philosophy

Module descriptions for courses with a substantial Cognitive Science component are given overleaf, these descriptions are adapted from the University calendar.

Discovering Cognitive Science
This module introduces Cognitive Science by considering contrasting approaches to modelling and understanding cognitive processes. The lectures describe important computational models from the Cognitive Science literature and relate them to research on human cognition, while in practical classes, students investigate and experiment with these same models using purpose-built demonstration programs. The behaviour of the models investigated here shows many striking similarities to human cognition, and is contributing to a new understanding of how the mind/brain works.

Models of Mind
This module continues the exploration of approaches in cognitive science begun in the first year. The common theme is the use of computer models to understand the function of the human mind and brain. The symbolic approach in cognitive science views intelligence as the manipulation of structured representations using rules. This approach will be investigated by examining symbolic models of the human cognitive architecture. A more brain-oriented approach is taken in the connectionist modelling (neural networks) and in computational neuroscience. These approaches will be explored through models of vision, motor control, and behaviour selection. Cognitive science is rapidly growing field so an important aim will be to track some of the contemporary trends in research in cognitive science.

Psychological Methods III: Computational Models
This module provides students with the basic mathematical and programming skills required for understanding and building computational models of cognition. These topics will be introduced in the context of interesting problems in Cognitive Science such as modelling human vision.

Cooperative Models of Mind
This module examines models of the mind inspired by the architecture of the brain and by the 'style' of biological cognition. A central thread is the idea that complex, intelligent systems are made-up of large numbers of relatively simple, co-operating sub-systems. The main focus of the module is on dynamic systems and connectionist (neural network) approaches to understanding human development and cognition.

Computational Neuroscience
This module deals with computational models of specific brain systems. Typically these models will be neural networks that are tightly constrained by the available neuroscientific data and whose circuits are based on the known connectivity of the corresponding neural tissue. Such models are making an important contribution to our

understanding of how neural circuits function in normal brains and dysfunction in damaged brains.

Visual Perception
This module explores selected topics in visual perception, in each case linking psychological, neuropsychological and computational approaches.