SERENDIPITY IN THE ENGINEERING CURRICULUM

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Abstract *¾ In this paper we present a different way to think of the process of teaching. We present a model that categorises teaching as a balance amongst and between three modes,* ***Active, Passive*** *and* ***Serendipitous****. We illustrate this with a case study of a first-year Computer Science course in Information Systems.*

Index Terms ¾ computer science education, serendipity in teaching, teaching information systems

INTRODUCTION

There are many ways in which faculty construct the process of their teaching. Formally, this may involve setting learning outcomes, aims and objectives for a course or module; practically it may involve a balance of delivery methods, lectures, discussions, laboratories, self-study materials. In this paper we present a different way to think of the process of teaching. We present a model that categorises teaching as a balance amongst and between three modes:

- **Active** : this mode encompasses the traditional area of "delivering the material" and is illustrated by lectures and other forms of direct guidance and interaction between staff and students. (The active mode is equally applicable where physical co-location is not possible).
- **Passive** : this mode can be described as "putting material in the path of learning". That is, it comprises material that is signposted for the student but is not delivered in a directive or interactive way. Examples of the passive mode might take the form of "supplementary reading", a compilation of web-resources, or a set of self-evaluation quizzes. One of the features of the passive mode is that it relies on students own information-gathering behaviours; to know how (and where) to look for materials.
- **Serendipitous**: This third mode is least utilised in formal situations. It requires the teacher to notice, and take advantage of, circumstances which cannot be predicted, but which engage and enhance the students' learning. These circumstances might have their generation from the students or from events in the world.

Although this model could clearly apply to the teaching endeavour in many disciplinary areas, we believe that it is particularly apposite for engineering education and illustrate this with a case study of a first-year Computer Science course in Information Systems.

"TRADITIONAL" CONSTUCTIONS OF TEACHING

The context of the model we propose is that it is rooted both in our practice and the literature of scholarship.

What we designate the *active* mode is well developed in institutional quality criteria and in literature which focusses on student activities & processes, for example Kolb's exposition of the learning cycle [1] and Biggs' perspective of student assessment as constructive alignment with learning objectives [2].

The McMaster Model of Medical Education and the subsequent explosive development of problem-based learning literature [3] describe well the sort of activities which we place in the *passive* mode. The central tenet of problem-based learning being that students are presented with a problem and then required to decide what learning they need to do (and where to get it from) themselves.

Our particular construction of the passive mode as requiring students to know not only *what* information to look for, but also to know *where* and *how* to look for it is exemplified in the excellent example of Harding's bank of disicplinary-relevant questions. Here students must find the answers to a randomly selected sample of questions which require recourse to a wide variety of sources from standards documents, through the popular press, to basic textbooks of mechanics.[4]

There are also many pedagogoic scholars and theorists who stress the importance of linking education with "real world" relevance. The influence of these can be seen in practices such as students undertaking projects sponsored by industry[5]. Although these activities take place wholly outside of the classroom (and therefore, in some sense, outside of the curriculum) they are the genesis and basis for our serendipitous mode.

DISCIPLINARY DRIVERS

The UK Quality Assurance Agency for Higher Education has recently delivered a series of subject benchmarks for each discipline [6]. These are "the outcome of the first phase of a major project designed to make explicit the general academic characteristics and standards of honours degrees in the UK". At the same time, the joint IEEE Computer Society/ACM Task Force, have been working on Computing Curricula 2001 [7] which aims "to review the 1991 curricula and develop a revised and enhanced version for the Year 2001 that addresses developments in computing

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technologies in the past decade and will sustain through the next decade". Both these documents recognise the necessity for the academic consideration of computing to be responsive to the techniques and technologies deployed in industry and to the uses of computers and systems by end-users.

Traditionally within the Computing Curriculum (and cognate disciplines), these drivers have been met by using case studies: real world events that have been picked over, digested and packaged for educational purposes: the Tacoma Narrows bridge, the London Ambulance Service Computer Aided Despatch System [8] and the Challenger disaster are all commonly used in the classroom.

There is no question that these are valuable resources which work well within an eduational context. However, they are sometimes criticised (out of the mouths of the students) for not being up-to-date. That is, they show students that what they are learning now might have been useful at some time in the past – not that what they are learning now has any appreciable relationship to the practical problems of the world today or the industry tha they are entering.

A CASE STUDY IN SERENDIPITY

Modern Information Systems are complex phenomena that involve detailed interaction between people, organisations and technology. Sometimes they seem to simply emerge, sometimes they have as a kernel an existing system which becomes "computerised", but mostly they are actively designed. Thus, the study of Information Systems is a central part of many computing degrees, and is a core foundational course for Computer Science students in the Computing Laboratory at the University of Kent.

We teach on this large (*circa* 250 students) first year course (called Information Systems). The course objectives are described to students thus:

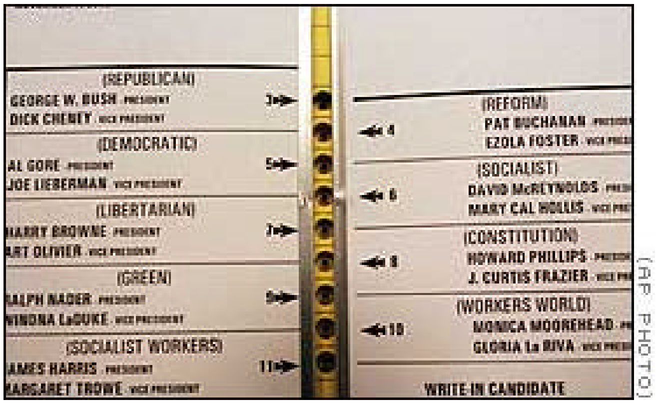
> Information is vital to us all. Individuals expect to have rapid access to information in their work, study and leisure while organisations must handle information effectively in order to survive. This module looks at the nature of information and introduces the techniques needed to build information systems.
>
> The objectives of this module are to give you some knowledge of modern information systems and skills in the techniques used to build them. By the end of it you should know how a range of organisations use information systems, what technical components are needed to build them and the factors affecting their usability. You should be able to analyse and design simple systems and record their analysis and design using a number of object-oriented techniques. You should also be able to prototype the implementation of a simple system using an extended relational database management system.
>
> You should be able to communicate, discuss, understand and practice communication, presentation and team working skills

In teaching this course we faced all the traditional problems of this area: the students have little experience of "real world" problems, or appreciation of their scale and complexity. We addressed this with traditional solutions. In the *active* mode we structured and prepared material which we delivered in lectures and small-group classes. We chose textbooks and provided references to specific reading. In the *passive* mode we required students to undertake open-ended tasks, where they would have to identify and contextualise information for themselves. For example, the first piece of assessed work on this course was one of observation of information "in the world"; we asked them to notice and name patterns concerning how information was actually used, for example how people made plans, what information-conveying materials people carried with them or the information carried on architectural signage on the University campus. These activities were acceptable within the terms of the course, within our professional responsibility as educators and within the scope of the learning we wanted the students to achieve, but did not address the pedagogic problems of the subject area in any other than traditional ways.

However, by the greatest good chance, the real world provided a superb illustration of the issues and problems of a complex information system in the US Presidental Elections of November 2000. The problems that were encountered in Florida (and, specifically in Palm Beach) had many characteristics that made them attractive as material for this course:

- There were initial HCI problems with the design of the voting form. These problems were compounded by the way in which processes in the election were conducted (in how votes were collected and counted) and in how absentee (or "postal") votes were dealt with.

THE PALM BEACH BALLOT PAPER, SHOWING AN HCI PROBLEM WE COULD NOT HAVE INVENTED



- Additionally, we had already presented material within the course that related particularly well to this area. For example, early in the course, as part of the historical contextualisation of Informaion Systems, we had delivered material (in the active mode - via lectures and supported by class notes) concerning the influence of Dr Herman Hollerith. Hollerith invented an electromechanical machine, which took perforated cards for input, and which was used in the 1890 US census - because it had been calculated that processing the 1890 data by hand (as had been done for the 1880 census) would mean that it could not be completed before the 1900 census. (His influence reached further than that when he later formed the Tabulating Machine Co. In 1911 this company, through merger, became the Computer-Tabulating-Recording Co. Thomas J. Watson became its president in 1914 and, in 1924 Computer-Tabulating-Recording Co changed its name to International Business Machines - IBM). The Palm Beach voting system had used a punch-card system, more than a century later, and this was one of the parallels we wanted to bring to the attention of the students.
- Best of all, this was not a constructed "case study"; there was no way for either staff or students to know where this story would end, would know *a priori* what lessons were to be teased out of the wealth of facts. As teachers, we did not even have control over the release of the material (the most basic control that a teacher has).

We took this opportunity that had so fortuitously arisen to respond to the real issues that the students could see emerging in the press. We scrapped the last three weeks of practical material that had been planned in favour of a focussed project that would allow the students to engage with issues embodied in large-scale voting systems, and demonstrate the skills they had acquired in the course.

Presentation to the students

We could not, of course, present this work to students in the active mode. We could not construct and deliver material on a session-by-session basis because we had no way of knowing what the important issues were going to be. So we structured the learning requirements in the passive mode, but with careful back-links to previous examples of active delivery. The project as set, was: "Your task over the next three weeks is to design a voting system for Palm Beach County, including a prototype of the voting mechanism you propose. This work is to be presented as a poster in the class of Week 12. Your design must detail *how people vote, how votes are counted* and *how you know who's won*."

We provided a number of references to external sources, in traditional *passive* mode, together with links to materials which had been previously delivered in the course:

IN-COURSE RESOURCES, AS PRESENTED TO STUDENTS

Things you might want to remember	Resources
When/why were punch cards were first used?	Lecture 3
What design techniques might you use?	Classes 3 & 4
Maybe brainstorming as a prelude to critical categorisation? Maybe use cases?	Classes 5& 6
Notions of reliability and trustworthiness	Lectures 15 & 17
What a good user interface must encompass	HCI lectures
What can you research/observe about how people use information?	First Assessment

We also provided a possible structure for their work on this:

OUTLINE PLAN OF POTENTIAL WORK, AS PRESENTED TO STUDENTS

Week 10	Brainstorm functionality. Categorise then research the areas where you need knowledge to inform your design. Research current situation (problem-structuring and the "incubation" period of problem solving. See Lecture 6)
Week 11	Work on design - both at the system level and the physical prototype of the interface
Week 12	Present your poster

Successes in teaching and learning

The component was, in some senses extremely successful - beyond even our expectations. The students demonstrated understanding and learning which they could have acquired in no other way.

1. Understanding of technical issues

Students proposed systems which utilised a variety of technical resources - always targetted to overcome problems they had observed.

- on-line, touch-screen voting – to avoid voter confusion about who their vote was cast for, this system had photographs of the candidates which formed the selection buttons
- systems for people to vote via mobile phones—so that disabled and house-bound voters are not disenfranchised
- OCR (Optical Character Reader) systems and systems which relied on picking up information on bar codes or magnetic strips (like the London Underground ticketing machines)—to ensure accuracy and efficiency in the count

2. Understanding of socio-technical implications

Some students concentrated on the steps necessary in the casting of a valid vote and one group separated the production of a vote from the act of casting it, demonstrating real insight into the socio-technical processes which underlie the simplest of acts in the modern world.

- In their system, a voter would go to a kiosk to produce a voting card. These kiosks could be numerous, situated in many diverse public places, and could utilise many familiar interfaces such as bank teller machines. There would be no need for secrecy, as this wasn't voting. A voter could produce as many voting cards as they liked, until they got it right to their satisfaction. A voting card would have the information (of which candidate/party the vote was for) encoded in machine-readable form (a bar code) on one side, and in human-readable form on the other (so the voter could be sure that the details were correct). The voter would then take the card to the polling station. Only at that point would eligibility to vote be checked, and the vote lodged. To preserve privacy, the card would be inserted into the ballot box with the bar code facing the scrutineer, and automatically tallied as it passed through the reader. Should there later be a dispute, however, the cards could be taken from the box and manually counted, using the human information on the other side.

3. Skills of information gathering and synthesis

The widespread nature of the problem allowed for many information-gathering possibilies.

- One particularly enterprising group focussed on the necessary trustworthiness in a voting system and based their system on the Lottery—after all, people trust their money to the lottery every week. However, they were unsure whether their knowledge translated to a different context and so set about finding out. They entered into an e-mail correspondence with the Florida Lottery Board and discovered that the Florida Lottery system "... runs like silk, handles more than 50 million transactions every single week" and has an established check and backup system: "we really never have had disputes about our games". They based their solution on this existing, widespread and accepted technology.

Unexpected successes

One of the successes was the enthusiasm with which students undertook this work. They were pleased to be wrestling with these issues and brought their humour and personalities into what is often a rather dry subject. This could be seen in some of the names they gave their systems, and we saw *The Touchscreenator*, the *Voting O'Rama*, the *Electrovote* and the *"Who Wants to be a President?" Voting System*.

Also, because we were dealing with issues in the world which were of international importance, these were of interest to a wider audience than we found in our classroom. Some students gave radio interviews on the work, and there was a substantial write-up of the experience in the University Newsletter. This outside interest was surprisingly affirming and motivating for the students.

Qualified successes ("failures")

Because we were unsure of the situation as teachers, we did not feel able to set this project as graded coursework. We delivered material on it (within bi-weekly lectures) and required work on it (within weekly small-group classes) but the production of the system carried no marks. Our reliance on the diligence and enthusiasm of the students meant that only about half the cohort actually submitted a poster.

ANOTHER SORT OF SERENDIPITY

Clearly, no teacher can expect (or predict) that the right circumstances will occur in the world to enhance any particular piece of teaching. We cannot hope for bridges to fall down, for airplanes to fall out of the sky or for elections to fail at the moments when they might illustrate the learning objectives of our courses. However, whilst remaining alert for these occassions, we have come to believe that we can use *whatever* is happening as the basis for our teaching.

Based on our successes with using serendiptiy in *Information Systems* we shall extend use of this mode into a new component of the course *Computers Software and Systems*, to be run from September this year. In this component, students will be asked to read a specified publication each week. For our subject we shall use a mixture of academic and "popular" publications, both on-line and print. Good candidates are *Communications of the ACM*, *Wired* and the *RISKS forum*.

We can plan and prepare for this in as much as we can choose the publications that they will be reading, but have no control of what will be published, what issues might arise, or what material we might be called upon to consider or discuss. What we can be certain of is that in this course (as in *Information Systems*), by serendipitously responding to events in the world, and by removing the artificial distinction between what happens in Universities and what happens in "real life", we will be building relevance into the core of the curriculum.

SUMMARY & CONCLUSIONS

This exploration demonstrates how "real world" relevance can be incorporated into academic courses by the way in which faculty construct the activity of their teaching. It posits a model which has three strands: active and passive mode (which reflect traditional pedagogic approaches) and proposes an extension, the serendiptious mode. We believe that this third mo de is particularly appropriate to engineering (and cognate) disciplines.

Of course, any change – be it a change for the better or otherwise – is problematic and requires changes in personal attitude and behaviour. There is no question but that using the serendipitous mode requires courage, as many of the props which we rely on as faculty are either absent or transformed. However, it is our experience that this mode is not only motivating, affirming and enthusiastically received by the students but is also unsually exhilerating for staff involved.

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