From Mathematics Teacher to Computer Assisted Learning Researcher

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Abstract. In this article, I discuss a journey from Mathematics and Computer Studies teacher in secondary school to an educational researcher in computer assisted learning. Along the way, in collaboration with other early pioneer teachers and encouraged by visionary education advisors a personal kit computer was constructed in 1978, an educational simulation created in 1979, before employment as an educational simulation developer as part of the UK Computers in the Curriculum project from 1980 to 1990. Although a specific case, issues of general interest about major upheavals in the educational and technology worlds and personal issues in an unusual and ground-breaking career are discussed.

Keywords: mathematics education, computer assisted learning, computing, computer studies, curriculum development, educational research

1. Introduction

1.1 University

I graduated from university in 1976 with a degree in Mathematics and Physics. I had undertaken two computing courses in my studies, one to develop programming skills in Fortran and the second, described as Advanced Computing, was simply to develop a more ambitious project, which I failed! These early days at university involved the punching holes in 80-column cards and constructing a stack of such cards, each of which represented one line of program code. The cycle of trial and error to improve programs took a day, leaving the cards at the computing centre reception on one day and collecting them and a printout on the next.

1.2 Teaching

When I left university, it was to work at an inner London school to teach mathematics – there were no facilities to pursue computing in this job, but the next year in 1977 I left and took up a post at another London school where programming was taught and thus begun my educational computing career.

2. The Early Days of Educational Computing in UK Schools

2.1 The State of the Art

This early career coincided with the development of microcomputers which became increasingly affordable for any school to explore as a focus for teaching computer studies or a tool for engaging children in thinking about other subjects. Until this moment, very few schools in the UK had any direct contact with computers except through local authority and higher education services to take mark-sense 80-column cards, carefully coded in BASIC with pencil marks before being whisked away on a motorbike to the local centre only to return a week later with a print-out saying 'Syntax error at line 10' and ready for corrections to be made by the learner – such was the experience in 1977 at the second school I joined.

2.2 Mathematics

My main activity was to teach mathematics and it was notable then that the Schools Mathematics Project (SMP), first developed in 1961 and taught to me in school, was coming to the end of its popularity. SMP was a mathematics curriculum designed partly in response to the Sputnik launch by the Soviet Union, which also led to the 'New Maths'. Much was done in SMP mathematics to provide an intellectual foundation for computer science, and just as real computers began to be available to children to explore, its modernism began a decline in popularity! In this school, the mathematics department and indeed the whole school was beginning a reappraisal of all curricula to focus on the challenge of mixed-ability teaching and seeking curriculum developments which could tackle this. One such development was the Secondary Mathematics Individual Learning Experiment (SMILE), which invited teachers to collaborate to design a resource-base scheme for students to follow individual pathways through an agreed mapping of tasks to key curriculum areas and levels. Although this school did not adopt the scheme, SMILE became hugely influential in my development and understanding of design for learning.

2.3 Computer Studies

Computers Studies in the school was taught to Certificate of Secondary Education (CSE) level, an examination through which students could attain an award at school leaving age (16) which was equivalent to a pass at the then predominant O-level qualification. The curriculum focused on a theoretical and historical account of the development of computers, an analysis of their component parts, a sense of the wider societal use of computers and their applications, some skills in flowcharting and a small amount of programming. In my first year, this programming was undertaken, as described earlier, through mark-sense cards on a weekly turnaround, but each year I taught brought change and new opportunity. The development of this subject was supported by an advisory service led by inspector Derek Esterson and advisor Bryan

Weaver who organized courses and meetings for teachers. In addition the school was part of a consortium of schools developing the CSE examination in what was called 'Mode 3' form – both the questions and syllabus were developed by teachers with both examination and coursework marked by teachers checked by the examination boards' moderation processes to assure quality. This creative and participative design opportunity was very influential for me and my future career.

2.4 Teletype Interactivity

A telephone line and teletype was installed in the mathematics staff preparation room. The teletype was an electronic typewriter that could print onto a roll of paper at the mercurial pace of 11 characters per second (a page of 60 lines and 80 characters per line might thus take around a minute to print). This equipment allowed interactive programming through the telephone handset placed in an acoustic coupler and modem connected to the City of London Polytechnic's minicomputer.

Fig 1: An acoustic coupler and modem – the telephone handset rested on the two cups to transmit and receive digital data encoded as sound frequencies

Although slow by modern standards, this facility permitted a quicker turnaround to develop a program, but was not located in the classroom and thus hard to integrate into lessons. On the other hand, it became a route to connect with other professionals, the local authority advisory staff and indeed other computer services in other higher education institutions through email. The only drawback was that the head of department ran an after school meat butchery business using the telephone for customers to place orders, and was not best pleased if I used it after lessons!

2.5 Kit Computers

In 1978, many kit computers began to be available to the general public to purchase and build. In my case, I saved up the £230 (about £1,100 in 2013 terms) for a NASCOM II single board computer. This computer used the then powerful Z-80 central processing unit, boasted 2 kilobytes of memory, three quarters of which was available to me to use in my programs, came with a keyboard and connected to a domestic television. I could (just about) save programs to audiotape, but had to write programs by directly entering hexadecimal codes into the memory, so spent time poring over the Z-80 instruction set to discover what was possible, and acting as my own assembler – writing mnemonics for instructions and translating into the hexadecimal alongside. A great deal of learning went on after assembling the kit with a soldering iron and I developed a profound understanding of the fetch-execute cycle and the underlying operation of a computer.

2.6 A Microcomputer for Education

In 1979 the school set aside budget for the purchase of a microcomputer which was designed and marketed to education. The Research Machines 380Z had been adopted as the standard for use in the Inner London Education Authority and some money offered to schools to help with purchase. This computer, although still storing programs onto audio cassette, was considerably more powerful, including the opportunity to use computer graphics on an 80 by 60 grid and a BASIC interpreter so that programming could be more readily related to real world problems. This computer displayed its output on a small black and white television monitor and was also capable of being connected through the telephone/acoustic coupler to interactive services and, more powerfully, to resources so that computer programs could be downloaded and used after saving to audio cassette. This connection could be made to both the City of London Polytechnic service and to other local authorities – I remember downloading new software from the then Hatfield Polytechnic in Hertfordshire. Unlike the modern internet, these were point-to-point connections made through individual telephone numbers, but despite this, there was a powerful sense of connectivity and opportunity that was remarkable for the time in such a humble setting.

3. Designing for Learning

3.1 Creating a Simulation

The new school computer became a regular visitor to my home, despite weighing several kilograms and being a two handed, two journey job to carry to my car. Ever since as a child seeing a computer simulate a frictionless ball, bouncing around a perfectly elastic snooker table on the television programme 'Tomorrow's World', I had craved the chance to make a program like it. I now set about writing a BASIC program to do just this, purely for my own gratification, and thus the program SNOOKER was born. I added pockets, friction, restitution (energy lost on bouncing) and an interactive opportunity to set the direction and pace of the ball. If it landed on a pocket a success message was displayed, varied to reflect the number of attempts it had taken. I had conceived it as a test of my capability and as a game, so proudly showed it to my students in the school. I was surprised to find they liked it, wanted to play with it together and argue with each other about the angles. One even went to the cupboard to find a protractor to hold up against the screen in order to estimate the angle to pocket the ball. It was my first experience of the power of the computer to support learning of another subject, and launched a career in computer assisted learning. The motivation, persistence and delight in the students' eyes had made a huge impact on my educational thinking.

3.2 Consolidating the Design Thinking

As a consequence of this success, I signed up to a course titled 'BASIC Programs for Teaching – a course on program writing' on the design of educational software which was being offered by the Polytechnic of the South Bank in London. This course was led by Morfydd Edwards and Susan Eisenbach and introduced me to the evaluation outcomes of the National Development Programme in Computer Assisted Learning (NDPCAL). Although that project had been at higher education level, the evaluation findings proposed four categories of computer use which might support learning: instructional, revelatory, conjectural and emancipatory. This offered me an early practical analysis to inform my own designs.

3.3 Professional development

Through all of these activities I met with other teachers in London who were developing educational software and joined the group 'Microcomputers in Computer Education' (MICE) led by Bryan Weaver, the advisory teacher for computer studies in the ILEA. Our goal was to collaborate to create interactive programs for learning concepts in computer studies itself – a typical example was to visually portray sorting algorithms.

My own proposed program was intended to visually simulate the layout and operations of the central processing unit of a computer and would respond to a simplified assembly language program. My intention was to bring these to life in a 'revelatory' mode (Millwood 1987) and relate them visually to the computer hardware.

Although there had been a growing interest in teaching programming concepts through animations in the context of higher education, it was new to be focussing such innovation on secondary school. Our work made impact on the practice of colleagues in the Inner London Education Authority and at the time was considered a vital part of the development of teaching computer studies there, with its work reported regularly in the newsletter distributed to computer studies teachers in London by the advisory service.

4. Research, Design and Development as a Career

4.1 Programming Full Time

By 1980, I realised that I wanted to spend all of my time developing educational programs and I set about looking for posts that might permit it. There was little or no commercial market at the time for such materials and the only place where I could see opportunity was in university education departments where curriculum development projects had been undertaken to research this new area. There were two key projects at the time. The first was titled 'Investigations into Teaching with Microcomputers as an Aid' (ITMA), a collaboration between The College of St Mark and St John and Nottingham University – it focussed at first on Mathematics education, but broadened into Geography and other subjects. The other was the 'Computers in the Curriculum Project' (CIC) based at the Centre for Science and Mathematics Education at Chelsea College London University. This project focussed at the time on science simulations for sixth form students and had been distributing software to schools globally on punched paper tape to be loaded onto central computers and operated by the kind of teletype that I had been using in school. Posts were advertised in both projects and I was offered the job with the CIC project, in the beginning to redesign the paper-type / print-out simulations for the new screen-based microcomputers.

4.2 Interoperability and Standards

A major concern for the CIC project was to ensure that owners of the varied kinds of microcomputer then available could access the software we developed. This meant either re-writing each program to suit the specific variant of BASIC and computer graphics / keyboard that each computer had to or find a way to write once using standards that would enable easy implementation in each platform. The latter course was developed by creating a library of subroutines in BASIC which attempted to provide a layer to separate machine specific issues from the educational and logical design of the program. I eventually became the leader on this task and created and maintained the guidance for a growing team of programmers in the project.

4.3 Development Methodology

The project also deployed and developed a methodology for the design and development of the educational experience. This involved groups of subject teachers working together with a programmer – ideas would be generated based on challenges faced in teaching together with perceptions of what a computer could do to tackle the challenges. Simulations of expensive equipment, complex or time consuming experiments or indeed dangerous manufacturing processes were often at the heart of the work, only lightly touching on the use of the computer to encourage debate, collaboration or make choices within difficult issues, although this became more prevalent as the project matured.

To develop a unit, the teachers would complete a form which outlined the design, share these with the project's leadership and once agreement found, the programmer would begin to work with one or two of the teachers on each idea. Key concepts included the program's navigational structure, the underlying scientific model and the development of a teachers' and students' guide.

The result of the team's work would be trialled in all the schools of the wider disciplinary group and observations brought back to an evaluative discussion which may have led to change, improvement or rejection.

Finally the guides would be typeset for publication, edited by a member of the CIC project, and the computer program would be checked on the platforms for publication before being duplicated on floppy disk.

Materials were then distributed through publishers Edward Arnold or Longman Group and promoted at conferences, professional development events and subject discipline meetings.

For me as a programmer, exposure to the educational and pedagogical debates as each program was designed led to an increasing mastery of these as key issues to the success of our work and thus programming alone did not satisfy!

4.4 Lecturing in Education and National Leadership

Towards the end of the decade I began to be more and more involved in the core business of the teacher education department within which I was employed. My new-found understanding of educational issues allowed me to lecture and supervise student's work. My role became part time as a mathematics education lecturer, visiting students in practice in schools and as a lecturer on a Masters level course relating particularly to computers in education.

At the same time, I took the post, based in the Computers in the Curriculum Project sponsored by the then national organisation Microelectonics in Education Support Unit (MESU) as a research fellow in software interoperability. I helped found the Educational Developers Software Forum, where I could exercise national leadership on the way in which we could tackle the burgeoning range of hardware and systems becoming available in the late eighties. I published studies which clarified the role of new software environments and their potential in educational computing.

4.5 Mental Models and Doctoral Research

As I was based in a highly respected educational research unit, attending seminars and taking part in meetings related to education more widely, I was invited to join the London Mental Models group led by the late Joan Bliss. This multidisciplinary research group involved staff in science, mathematics and history education, but also in language, cognitive psychology, educational computing, expert systems and artificial intelligence. The group provided me with a regular and powerful discourse to engage with in relation to the role of computers in learning and in particular, analysing the nature of modelling and simulation software and its potential for learning. I participated in the meetings and contributed ideas to seminars considering models of learning with technology.

This engagement led to a proposal to undertake PhD research with Prof Paul Black. I was invited to undertake two tasks to enter the course – an essay on technology and learning and to follow the Masters level course in Research Methods. I completed both and was about to set out on this course until swept up in the technological wave of interest in multimedia, which led me to work with Prof Stephen Heppell in 1990 to build the Ultralab research team. The PhD has recently (2013) been re-engaged with, but now reported as a retrospective reflection on my practice!

5. Conclusions

This article describes the first half of a career which has always been inter-disciplinary and constantly compromised by the emergence of technologies inviting re-appraisal of the direction taken. As Alison Hudson points out, there are many professionals now operating as learning technologists or educational developers, with much confusion about their academic and professional status as the disruption made by new technologies continues to be felt in both schools and higher education.

Hudson's study suggests that:

> *"...both groups occupy a highly politicised position, are affected by the shifting value of social, cultural and economic capital in the constantly changing higher education, are subject to struggle regarding 'position' and agency and are susceptible to the demands of new power regimes and technological solutions."* Hudson, 2009, Abstract

This struggle with 'position' has made identity difficult, since the combination of disciplines necessary to carry out my work has shifted from instructional design, to multimedia creativity, and although not reported here, to course design and ultimately the design of school and higher education itself. Thus I have never 'settled down' in any subject disciplinary sense, instead obtaining coherence from the focus on design, development, marketing, teaching and leadership in the creation of innovative 'products' at many levels.

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