25 May 1973

The Editor,
'Computer Weekly',
Dorset House,
Stamford Street,
London, SE1.

Dear Sir,

I have submitted to you an article entitled:

Computer Education in Universities.

Please could you let me know in what issue you intend to publish this article; or if you do not wish to publish it, please let me have back my manuscript, so that I may submit it elsewhere.

Yours faithfully,

(C.A.R.Hoare)

Computer Weekly

Dorset House Stamford Street London SE1. Telephone 01-928 3333

Published by IPC Electrical-Electronic Press Ltd. A member of IPC Business Press Limited.

JCH/AOA

13th December, 1972

Prof C. A. R. Hoare,
Department of Computer Science,
The Queen's University of Belfast,
Belfast BT7 1NN
Northern Ireland.

Dear Prof Hoare,

Thank you for your letter of December 4 and for the offer of an article on Computer Education in Universities.

I should certainly be interested in such an article, which should be 1500-2000 words long. If possible, I should like to receive a draft before the end of January, together with a photograph of yourself and a short biographical note to accompany the article when published.

I am quite happy that you should refer to other recent articles in Computer Weekly if you wish to, but I leave that to you.

The article will be paid for at the rate of £1.50 per 100 words, for all rights, on publication.

Yours sincerely,

J. C. Hipwell

J. C. Hipwell
Editor and Publisher.

acknowledgement?
01-261
8000

12 January 1973

01-261-8000

The Editor,
Computer Weekly.

Dear Sir,

Herewith I submit, as requested, two Xerox copies of an article on Computer Education in Universities, for publication in Computer Weekly.

I also enclose a photograph of myself and a brief but relevant prospectus.

Yours sincerely,

(C.A.R. Hoare)

Tony Hoare has been Professor of Computer Science at the Queen's University, Belfast, since 1968. He gained the basis of his computer experience in the employment of a computer manufacturer (Elliott Bros.), where he was concerned with software design, implementation, management, and research. He has published some forty articles and lectures on computing topics.

His university education included a study of Latin, Greek, Ancient History, Philosophy, Russian Language, Statistics and Probability. In this article he draws together the diverse strands of his education and experience to give his view on the role of the University in the education of the computer professional of the future.

Computer Education in Universities

C.A.R. Hoare

A primary aim of setting up degree courses in Computer Science at Universities is to educate the Computer Professionals of the future. So the vital question for Universities is "What sort of professional will we want?". The answer is much the same as one would give for a doctor, an architect, a lawyer, or any other professional.// Firstly, he should have a broadly based knowledge of his subject. Of course, he cannot know everything about everything, but he is willing and able to undertake and master any new speciality as it is required. And he should never regard any aspect of his subject as a closed book, ~~to him~~.

Secondly, he must keep up with the rapid development of his subject by continued study of the learned journals, by reading new books, and by attendance at conferences and courses; and he should himself be able to make the occasional contribution (but will always complain that he has no time).

A third characteristic of a professional is that he tackles even the most routine aspects of his profession with skill and accuracy. This is so important in computer programming, where the quality of the product depends so much on the appropriateness of the many thousands of detailed design decisions that go into it.

Apart from skill in the routine, the professional should really show his mettle in new projects, and in unfamiliar situations. He should have that insight needed to see the essentials of a new problem, and the spark of invention to see its solution; but he will also know when it is best to use or adapt the well-tried methods of the past, if they will serve the purpose.

A most important characteristic of the professional is that he can communicate in the written or the spoken word. He can talk technicalities to his colleagues, ~~principles~~ cost and effectiveness) to his clients, and generalities to the layman. He can make a case for his projects, justify his opinions, and defend his decisions.

And finally, a true professional is distinguished by his dedication and enthusiasm for his craft. He works at computers most the time, talks about them at other times, and thinks about them at any time. His adherence to a professional ethic follows so naturally from this that he has no need of a formal codification to keep him from malpractice.

This then is the ideal of a computer professional. There are many working now with computers who measure up to this ideal. None of them have a formal degree qualification in Computer Science; many do not have a degree at all. So a degree is obviously not a necessity to the professional of the present day. How can it contribute to the number and quality of the professionals of the future?

The most obvious product of a University is knowledge; this must be broad, and cover the whole subject, embracing both hardware and software, machine codes and high level languages, compilers and operating systems,

As well as a knowledge of the separate topics, theory and applications, the student must develop an understanding of the relations between them. A student should also select a few topics to study in great depth, to develop his understanding, his confidence and his ability to do so again for any other topic which will be required in his professional career.

Of course, many of the subjects of study will not be directly relevant in the first few years of his professional employment. Take, for example, compiler construction. Very few graduates will obtain employment in writing compilers for a computer manufacturer, (although a small influx of good graduates can do nothing but improve the appallingly low quality of most current compilers). Nevertheless this subject is essential to convey a proper understanding of the relationship between hardware and software, between the high level languages mainly used for programming, and the machines on which the programmes are executed. In addition there are more direct benefits. A man who understands his programming tools is likely to select and use them more effectively. He can devise methods and set up standards to help others to use them more effectively. The techniques of syntax recognition and the importance of error diagnosis are directly relevant to all symbolic input from man to machine. It is for these reasons that a course or option on compilers has a valid place in a Computer Science curriculum at University.

The knowledge of a computer science graduate will rapidly cease to be of use to him if he has not the interest and application to keep it up to date. As a student he should acquire the habit of reading, comparing, and evaluating articles which have appeared in Computer Journals, and using them in his own programming practice. This can be encouraged by the method of the essay and tutorial, which are traditional in the study of the humane subjects at a University.

The development of the necessary programming skills of the computer professional presents a fascinating challenge for computer education. We can elucidate and teach the principles of program design and accurate implementation, the maxims for systematic program validation and testing~~s~~ and the standards of good documentation. We can set practical programming exercises, and also larger-scale projects. But the only way in which we can really develop good programming habits is to read and criticise the programs and documentation~~s~~ of our students, and where necessary, make them do it again. Until we do this, we cannot eradicate the most unexpected bad practices which they sometimes fall into. I am convinced that a good programmer can only acquire his skill by a form of apprenticeship to a master of the craft.

A second method of developing these skills is by reading good programs written by others. These should include both short ingenious algorithms embodying generally useful techniques such as sorting and searching, as well as large programs which have been superbly documented for this purpose. For example, a compiler course should be supported and illustrated by the study of a complete compiler; and the student's understanding can be reinforced and tested by asking him to make minor extensions and modifications to it. Thus he will fully realise the purpose as well as the methods of good documentation, and obtain an introduction to the art of program maintenance, which will be of increasing importance in the professional life of programmers of the future.

Insight and inventiveness are an even greater challenge to the educator. We can give the opportunities for it to germinate; we can recognise and foster it when it has. But perhaps the closest we can get to inspiring these qualities is in teaching of the theory of computation. Apart from conveying a vital understanding of the solute limits on the capabilities of computers, the theory of omputation gives the student a new range of conceptual tools which he can apply to new and unfamiliar problems; it gives training in the art of abstraction, which is fundamental to the establishment of human understanding and control of complex phenomena; it shows how to transform one problem into another as a ~~vital~~ preliminary step in its solution; and finally it inculcates ~~the~~ a degree of mathematical and logical rigour which is essential to the design and implementation of large programming projects.

Skill at communication is the hallmark of an educated man, whether the subject of his education is Latin or Civil Engineering, Anthropology or Computer Science. It can be developed by the traditional methods of essay writing, tutorials and seminars, ~~conducted by the students, themselves,~~ and, most important, intense discussion between the students themselves. They must be taught not only to write programs, but to design them, describe them, document them, and discuss them in ordinary plain English, for different classes of audience. The significance of computers in the life of society, and the speed with which they have been introduced, gives the computer professional an especial obligation to make himself widely understood.

And the final quality required is dedication and enthusiasm. We take it for granted that the university teachers themselves have this quality, and that they combine it with a dedication and enthusiasm for teaching, which will make each course and option attractive and interesting. The rest is up to the student; some of them acquire it and others do not, and it is impossible to know in advance. At a University those that are not so keen on computing have plenty of opportunity to study some other subject, either by itself or perhaps in conjunction with computing. It is particularly ~~attractive~~ appropriate to provide joint courses in computing together with a subject in which computers can and should be applied; (perhaps Business Studies, Operational Research, Geology - indeed no subject is excluded by this definition). Successful use of computers in these areas depends a great deal on a thorough understanding of the area, as well as of computing techniques. ~~and~~ A graduate with a joint degree could be exceptionally valuable in extending the successful application of computers; furthermore, he will have flexible career prospects in either of his subjects, or in ~~the interface between them.~~ both.

After my idealised picture of the computer professional, I have painted an idealised picture of his education. It is worthy of note that the qualities I have mentioned describe not only the computer professional, but also the generally educated man, whatever the subject of his education.- ~~knowledge and~~ understanding developed by continuing study, skill and accuracy, insight and inventiveness, communication, dedication and ~~enthusiasm~~. Th~~ese~~is ~~are~~ is the reasons why Computer Science is a suitable subject for study at Universities, and why the University is such a good environment for the study of Computer Science.

Finally, I must emphasise again that there are two factors which go into the making of a professional; they are education and experience, and of these the second takes longer and is more important. In any subject, a new graduate will be of little benefit to his first employer in his first year; but his value should increase as he settles down in his new surroundings; and continue increasing as he gains further confidence and experience; and for the best graduates, their full potential will not be realised for ten or fifteen years or more after graduation. A University education is only a beginning, and cannot pretend to be more. After that, it is up to the ~~student~~ graduate and his employer to complete the development.