SECTION ONE
University Education

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University Education in the Next Century

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1. The Present

There is no doubt that the science of astronomy is now in an exhilarating state. We are in the era of the 10 m optical telescope. Radio astronomy rivals optical astronomy in both positional precision and sensitivity. Observation from space has opened access to a wide range of frequencies in the electromagnetic spectrum. The spectacular achievements of the Hubble Space Telescope underline the success story of space astronomy. At all wavelengths, detector technology has made striking advances in sensitivity and, coupled with cheap, sophisticated and powerful computers, raw data can be transformed into useful scientific data with breathtaking speed. One has only to add up the number of papers published in the three major astronomical journals to realise that one must read 100 journal pages a day (every day) to keep up with the literature in these three journals alone. Astronomy at the close of the 20th century is indeed exhilarating.

But there are indications that all is not well. Not unexpectedly the cost of new astronomical facilities is being called into question. Currently, no one nation can afford to finance a new telescope of the 10 m class and international consortia are now a commonplace to finance such facilities, e.g. the ESO 4×8 m telescopes in Chile. The great cost of science more generally, is now being seriously questioned, particularly in those areas of science which are fundamental, e.g. astronomy, particle physics, and which are not regarded as being currently relevant to industrial and commercial activity. International Economic Institutions are raising the issue of whether or not the next stage of fundamental science will be affordable at all. L. Woltjer and F. Praderie at the 1995 European Astronomical Society Meeting (JENAM, Catania) addressed the economic constraints of the future and both concluded that the optimistic outlook would be level funding at present rates. Much greater international co-operation would become the norm - not just confined to major projects. The consequences for the development of the next generation of astronomical facilities are not yet easy to quantify.

A second problem facing astronomy is that of adverse environmental impact. A vibrant and creative technological society has endowed astronomy with outstanding instrumentation both on the ground and in space. Yet that same civilisation, by that same energy that has provided wonderful astronomical tools, could render the science of astronomy impotent. Our civilised life styles are creating impediments to astronomical observation on a wide variety of fronts - ground vibration, increasing atmospheric extinction, electromagnetic pollution at all wavelengths, the increasing amounts of space debris. It is possible to envisage scenarios in the not too distant future when any form of astronomical observation may well be impossible to sustain because the activities of a technological civilisation will overwhelm faint cosmic signals. Astronomers, as much as any other terrestrial citizens, enjoy the fruits of technology - many of us came to this Colloquium by air, exploiting radio technology for safe navigation and good communications, enhancing cloudiness through aeroengine exhaust products. Astronomy has yet to reach a modus vivendi with a society which is not always well disposed to the interest of astronomy - particularly where profit is involved. The future for astronomy education could be impoverished were adverse environmental impact on astronomy to be allowed to worsen significantly.

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Student attitudes to education have also changed in the last 20 years. Changes in school education, an unfavourable employment environment and the introduction of the concept of the student as a "customer" have all had a significant impact on university education. It could be argued that increasing undergraduate numbers would have brought about similar changes. In astronomy - a minority interest - one might have been expected to escape much of the adverse consequences of these changes. However, that has not happened. Flexibility, informality, close contact with students has been lost and prescription and formality are now the norm and obtrude between teacher and taught. This has not led to "quality" in educational experience despite emphasis on demonstrating achievement of prescribed quality standards. This is something which I can only regret as a loss. Students on degree studies should have the privilege of being treated as individuals, to explore and develop their potential - particularly so as astronomy is a small subject in terms of numbers but which depends greatly on the creativity and initiative of individuals. As an example of what I mean by "quality" in educational experience let me only cite ability of students to articulate individual courses. There is a strong tendency for students to perceive a "course" as an individual entity which must be learned in order to achieve a satisfactory performance in the examinations. While students cannot be faulted for wishing to perform well, they can be faulted for not being aware of intercourse relationships. We seem to organise degree structures in such a way that intercourse relationships are not made manifest. As customers, students may decide a particular course is not "relevant" only to find that it was essential, but not a pre-requisite, for a subsequent course perhaps in another year of study. To cope with student numbers on the basis of declining resources, even practical courses - an excellent way to provide articulation between courses - are being so streamlined and formalised that the articulation process is being diminished. But it is encouraging that articulation can be quickly resuscitated by placing students in a teaching situation where they must draw widely on their accumulated knowledge. For the future we must try to ensure that articulation within degree courses is given adequate attention.

2. Influence of the Present on the Future

The major uncertainty for the future is funding for major new facilities whether ground based or in space. If level funding is the best that can be expected, what impact will this have on astronomical education? It is unlikely to have significant impact on the provision of astronomy degree courses since they are such a small component of the university sector. But if the pace of astronomical research slows, there will be impact on undergraduate recruitment. Young people find astrophysical and cosmological research, like particle physics, a great incentive to study physical science at university level. If these areas are not producing excitement and stimulation, undergraduate recruitment may remain at current levels. The numbers of school leavers taking A-level physics (A-level is the pre- university, school leaving qualification at age 18 in the UK) is declining year by year. Departments of Physics and Astronomy are struggling hard to maintain current intake rates. But there may be a glimmer of hope. Curtailment of expenditure on large international projects may lead to freeing of support for less capital intensive projects - such as telescopes optimised for particular purposes and, perhaps naively but very hopefully, for stipends for more astronomical personnel. It may be that career prospects and improved access to quality (if not large) facilities may encourage a modest increase in the astronomically motivated in physical science degree courses.

If adverse environmental impact on astronomy continues to grow, and there is no immediate sign of any amelioration, then there will be a very depressing decline in un-

dergraduate numbers with astronomical interest - whether we talk of degree students or students taking an elective astronomy course. If the conditions for astronomical observation become compromised, no undergraduate of ability will waste time on a dying enterprise. Adverse environmental impact is not just a threat to sustained access to high level astronomical observation but could be a real menace to undergraduate recruitment in the future. It is therefore vital, both for astronomy as an observational science and as a worthwhile educational experience, that adverse environmental impact is opposed with vigour at all levels.

We must also endeavour to provide an educational experience of excellence for our students. That, in my view, means providing them with degree courses that reflect the science of astronomy as currently perceived by research scientists and teachers. We do our students, or our science, no favours if we offer anything less. Pressures to make university education more relevant, more geared to wealth production, more geared to the needs of industry, commerce and the community need to be strongly resisted and rebutted. As astronomers we have a duty to maintain the quality of our science and the education of our successors is primary to maintaining that quality. It is an area over which we equivocate at our peril.

But we must also accept that such a policy may well, in the next century, lead to reduced numbers of students taking specialist degrees in the physical sciences. We may have to accept that as an initial condition. What I have found encouraging in recent years is the explosive growth in numbers of students not taking specialist degrees but who still wish to study a diet of physical science. This may well be where the future lies. While there will remain a residual interest in specialist degrees, we may have to accept that many young people are not prepared to make the commitment necessary to sustain them through a demanding specialist degree course. But young people are interested in acquiring scientific literacy. They want to know about cosmology, particle physics, the interior of the Earth.... As a society we need graduates who have a wide range of scientific knowledge and a good grasp of how that knowledge is obtained in the laboratory *and* in the field. The latter is important for the future - physical science if it is to play a real role in environmental matters (as it assuredly must), must educate its students in real life, non-laboratory situations. Astronomy, Geophysics, Meteorology and Oceanography, to name but four, are excellent physical sciences which are not only laboratory based. Students need to appreciate, that even in the physical sciences, there may not be a knowable correct answer. Students need to see that environmental data suffers from all manner of deficiencies and that they must make judgements on the basis of such imperfect data. They must be aware that in some circumstances, the wrong scientific questions are being asked because we do not yet know enough to formulate the correct questions. It seems to me that such training will be of vital importance for the future if there is to be a real increase in the levels of scientific literacy in the next century. Astronomy, in the company of like-minded sciences, must ensure that it has a major input into any new physical science curricula which responds to the widespread need for scientific literacy - a literacy as important as communication and mathematical skills. Astronomy, in particular, should play a central, major part in such curricula.

3. Conclusion

In looking forward I have noted that the outlook for Astronomy in the next century is not universally bright. There are many factors which could operate to the detriment of astronomical research. However, there is also cause for some restrained optimism that there could be improvement for astronomical education even though curtailment

of research opportunity could reflect in a reduction of undergraduate numbers taking specialist degrees in the physical sciences.

Where optimism is engendered is in opportunities to develop education for scientific literacy. Given the lack of real public understanding (as opposed to mere "awareness") of science, despite great effort by scientists, teachers and the media, there is a major need to address widely based education for scientific literacy. Indeed this may be a growth area in the next century. Astronomy must lie in the vanguard of such curricula, playing a major and significant role. As a science astronomy is well equipped to do so - the objects of study are available to all, it uses a variety of sciences to deduce astronomically significant information, it deals with observations under circumstances which are frequently not ideal in the laboratory sense and it encourages judgement in analysing situations where the evidence may have to be weighted for significance. In extreme situations, a study of astronomy demonstrates that there are scientific problems so challenging that they may be beyond investigation with the tools available or lie outside current conceptual experience or even both.

We must not be shy about the educational value of astronomy. Our challenge is to ensure that astronomy plays a major role in future physical science education and that the efforts of a small science are not overwhelmed, or sidelined, by necessary partnerships with a range of other, larger, sciences claiming sole rights to setting the framework whereby scientific literacy can become the prerogative of a large number of people. The evidence of public understanding of science now underlines the long road that remains to be travelled and the major challenge which our science must face, and conquer, if our species is to survive through the next millennium. Our task is no less than that.