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ABSTRACT

Statistical comparison of trends shows that the decline in the proportion of Australian matriculation students studying science subjects is less than that in the United Kingdom. In Australia, the decline in the proportion of new tertiary enrollments in the sciences occurs primarily in the applied and professional science courses which have quotas restricting enrollments. The increasing female enrollment in universities, primarily in arts and social science courses, contributes to the apparent drift in the proportion of science students. There is little evidence that uninspiring school science courses contribute to the decreasing proportion enrolled in tertiary science courses. A more serious drift is the decreasing attraction of teaching for professionally trained scientists: this may be remedied by improved employment conditions, including opportunity for periodic intensive retraining, and a flexible salary scale. Drifts in educational philosophy and from the compartmentalized scientific disciplines have implications for science education. (AL)

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STANHOPE ORATION: DRIFTS FROM THE SCIENCES

It is customary for an oration to commence with the speaker recalling the virtues and exploits of the distinguished person, after whom the oration has been named. The Stanhope Oration is unique in that R.W. Stanhope is very much with us and that he continues to make vigorous contributions to science education in Australia. The size and vigour of this eighteenth meeting of CONASTA itself testifies to the very real growth which has been initiated by Mr Stanhope's leadership. It suffices then to acknowledge these contributions and to look forward with anticipation to the fruits of his higher degree work at Macquarie University on Junior Science courses.

I should like to express also, at this point, my sense of the honour which the Australian Science Teachers Association has accorded me in asking that I deliver this Stanhope Oration. In my view, a basic viewpoint on education, and science education in particular, is that real progress is only made after a frank and sympathetic exchange of ideas and experience has taken place between all those involved in the overall educational process. This contribution is offered, then, not as some Delphic pronouncement of 'what is' and 'what should be' but rather to serve as a basis for initiating continuing discussion of some fundamental issues in science education in Australia.

By way of introduction, a speaker often elaborates and justifies the title which he has chosen for his oration. (Of course, a more effective practice might be to expect the speaker to justify to his long-suffering audience what he did say in the light of the intentions claimed in his introduction.) The title 'Drifts from the Sciences' was only chosen after some soul-searching. The word 'drift' has some emotive implications; one connotation is a somewhat aimless movement. In education this suggests a situation which gradually develops without conscious planning and perhaps even without conscious realization. On the other hand, the choice of 'trends' would have connoted a gradual movement in a generally specified direction. To claim foreknowledge of an ultimate direction in education would have been presumptuous since education is subject to interplay of many changing social circumstances. And so, 'drift' was chosen. 'The Sciences' will be used with two general meanings. In the first, it will be taken to mean not only courses in pure science but also courses in technology and applied science, such as engineering, and in the professions, such as medicine and dentistry, all of which involve courses based upon training in pure science in secondary and tertiary institutions. In the second connotation, sciences will be taken to mean the accepted scientific disciplines such as physics, chemistry and zoology.

The plural form in 'Drifts from the Sciences' is also deliberate since I believe there are several concurrent drifts operating. At first I shall consider the most publicised drift, namely the alleged decreasing proportion of students undertaking scientific studies at late-secondary and at the tertiary level. Subsequently, I shall comment on drifts from the scientific disciplines themselves, drifts from the teaching profession in secondary schools, and some drifts in educational philosophy and its impact on science courses.

The basis of concern

The concern which is expressed for any decline in the proportion of students studying science, and its derivative applied sciences and science professions, is professed on two grounds. Firstly, every nation now depends to a great extent on adequate numbers of qualified scientifically-trained and scientifically-minded manpower and there is concern that these national needs may not be met. The availability of science teachers to educate the rapidly rising teenage population is an example. Secondly, there is concern that the status of science, which is a basic component

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in our contemporary culture, should be maintained lest a growing proportion of our youth grow up ignorant of, and perhaps hostile to, this cultural force pervading our community. This second concern may be expressed both as a national one and as an individual one. If education is to achieve self-fulfilment for each individual, then it is important that the individual be given adequate opportunities to understand the cultural nature of science. Whereas the first concern is essentially a vocational and professional one, the second concern involves a more general appreciation of science. These two concerns must be recognized when one enquires if there is an actual drift from the sciences in Australia.

It may seem extraordinary that there is not agreement as to whether there is, or there is not, a drift from the sciences, in the sense of fewer students studying sciences. For example, in May 1968 the Australian Academy of Science organized a Symposium on Science, Technology and Society. Here, a major speaker quoted statistics which were taken to 'prove' that there was an almost equal drift as has been already demonstrated in the United Kingdom. Yet only last week in Sydney, at a meeting of the NSW Science Teachers Association, a member of the Australian Universities Commission stated that the statistics showed that there was no drift from science. Needless to say, both distinguished gentlemen were interpreting the same basic statistics! The discrepency stems from an inadequate definition of terms. To assist our analysis of the Australian statistics, and to identify some factors which could contribute to any possible drift, it will be helpful to examine first the situation in other countries.

The drift in England and Wales

In February 1968, the 'Dainton Report' was tabled in the United Kingdom Parliament. This report was prepared by a committee under the chairmanship of Dr F.S. Dainton, Vice-Chancellor of the University of Nottingham. It is significant that an interim report, based on the type of gross statistics which I shall employ for interpreting the Australian situation, was decidedly more optimistic than the final report, which had the benefit of a statistical analysis of individual students' choices and careers.

Table 1 suffices to establish the general situation. Because of the very specialized nature of the Advanced or 'A' level courses in England and Wales together with the strict entry requirements into their universities, students in science and technology courses may only be recruited from the Science Group listed in Table 1. The Mixed Group characteristically undertakes only one science subject and this often not mathematics, which is a key pre-requisite to the physical sciences; this group does not normally enter the sciences. The Non-Science Group embraces the various arts subjects, sometimes designated as the 'Humanities'. As in other countries, the size and proportion of the science group is a product of three factors, each of which changes with time:

1 the size of the population in the age group normal for that school year;

2 the proportion of this population group which continues its education to that point; and

3 the fraction of this group which opts to undertake the science-type course.

Two major conclusions follow from Table 1. The first is that since 1962 the percentage in the science group has fallen linearly with time and there is no sign that this fall is being arrested. The second is that the actual number of students able to enter university science and technology courses rose to a maximum in 1964 and thereafter the number has *fallen* in a time when the total sixth form population has *risen*.

The Dainton Report concludes that the 'gravity [of this drift] lies in the *deficiencies that will develop* if present trends continue, rather than in the numerical consequences to date! This comment refers particularly to the criterion of national vocational needs.

The conclusions as to the cause of this drift were:

the concentrated study of science subjects at 'A' level;

a drift by students to a greater breadth of study (notice how the size of the Mixed Group in Table 1 is rising);

a growing interest in the social sciences, practical subjects like accounting, and cultural subjects like music;

many students dropping mathematics at 'O' level;

the need for students to choose a science-oriented course three years before 'A' level at the age of about fourteen years.

With respect to school courses, the Dainton Report recommended a greater breadth of study in the sixth form; that all students should normally study mathematics until they leave school; and that 'breadth, humanity and up-to-dateness must be infused into the science curriculum and its teaching'. (The Australian science teacher will recognize the last exhortation as a familiar clarion call; all that is not answered is to how these desiderata are to be achieved!

The gloomy predictions seem to be borne out also by enrolments in university science and technology courses; these fell from 46.0 percent in 1962 to 40.6 percent in 1966. Perhaps even more serious is the decline in quality of the students entering the science

TABLE 1

Number of pupils in first year of sixth form on 'A' level courses: England and Wales

Year	Science group '1000	%	Non-science group '1000	%	Mixed group '1000	%	Total
1962	32.7	41.5	38.3	48.6	7.8	9.9	78.8
1963	35.9	39.6	45.3	50.0	9.4	10.4	90.6
1964	40.1	37.5	54.5	50.9	12.4	11.6	107.0
1965	38.4	35.4	55.9	51.4	14.3	13.2	108.6
1966	37.5	33.8	58.3	52.4	15.3	13.8	111.0
1967	36.5	31.5	61.3	52.7	18.4	15.8	116.2
1968*	35.0	29.9	63.0	53.9	19.0	16.2	117.0
1969*	34.6	28.4	66.2	54.4	21.0	17.2	121.8
1970*	34.5	26.8	70.6	55.1	23.3	18.1	128.4
1971*	34.2	25.4	75.0	55.5	25.7	19.1	134.9

*After 1967 numbers are estimated; the numbers quoted for 1968 and later are the means of estimated upper and lower limits quoted in the 'Dainton Report'.

TABLE 2

Some subject choices by sixth form students in Scottish secondary schools (expressed as percentages of all students)

SUBJECT	1963	1964	1965	1966	1967
Mathematics	40.1	42.9	41.7	40.9	38.5
Chem-Phys (av)	44.5	43.5	43.6	39.5	38.8
Biology	3.7	5.2	7.5	10.0	11.3
English	89.3	89.0	88.7	89.5	86.9
French	50.1	44.3	43.7	44.1	42.5
History	29.7	25.6	25.5	25.9	27.6
Commercial subjects	12.6	13.8	15.2	18.6	19.7
Homecraft	6.5	10.8	10.8	11.4	10.9

course. For example, if we set a score of 5 for an A grade, pass at A level 4 for a B grade pass, 3 for C, 2 for D and 1 for E, then the minimum score for entry into English universities in 1967 is as follows:

Medicine (12)
English (11)
Arts, Economics, Law (10)
Biology (5)
Mathematics (4)
Chemistry and Physics (3)

Again in Colleges of Education, in which 85% of new enrolments are in arts-type courses, only 3% of the science students had one 'A' level pass or more whereas 11% of the arts students had one or more 'A' level pass.

The drift in Scotland

The Dainton Report notes that the requirements for breadth of study, delayed specialization and a modern outlook of courses are met, to some extent, in Scotland. It is significant that the secondary Educational system of Scotland is very close to that in most Australian states and university entry and course arrangements are remarkably similar. It may be noted, in passing, that Scotland also operates a centralised education system which, with adequate inservice teacher training changed rapidly to modern curricula. Again the parallel to Australian states is striking. By contrast, the English system of local education authorities draws on more local community involvement. It can however be idiosyncratic and resistant to change. An example is the relatively slow adoption of the new Nuffield courses.

Table 2 summarises some subject choices by sixth form students in Scottish secondary schools. The traditional entrance into Scottish universities has required four Higher Grade passes. The most common science-oriented course in sixth form would be mathematics, chemistry, physics and either a foreign language or English. An 'O' level pass in a language or English, if not taken at Higher Grade, is also required. We then have a pattern which has remarkable parallels to Australia. Chemistry and physics have very similar enrolments and can be averaged. Enrolments in mathematics are fairly comparable to the chemistry-physics average.

The Dainton Report comments that there has been a slight decrease in the science group from 1963 to 1967 but it is not thought to have the same consequences as the large 'swing' in England. Other features in Table 2 which are significant, and which have Australian counterparts, are: the steady rise in biology, the even larger decrease in French, the steady nature of history, and the marked increases in commercial subjects and homecraft. In my own opinion, the choice of subjects in the non-science area is more restricted in Scotland than in Australia. This factor may also tend to hold science enrolments at a fairly constant level. Finally one might also note that about half of all sixth form Scottish students study at least one science subject, that is taking the sum of the chemistry-physics and biology entries. We shall have occasion to use this same rather crude criterion for Australian conditions.

International drifts

In western Europe, similar relative drifts from science appear to be operating in the Netherlands and Germany. Only France appears to be experiencing a trend towards science and this appears to stem from French pupils being directed into courses with a science bias. For example, 73% of all students in their baccalaureat year, or matriculation year, took science type courses in 1963-64; this included 71% of all girls. However the French students appear to drop out at a high rate before entering a university. In universities in 1962-63, 45% of all UK students undertook science and technology courses whereas this figure was 35% in the Netherlands, 32% in France and 26% in the German Federal Republic. These figures prompt the question as to what is the optimum proportion for science and technology courses and we shall return to this problem later.

The Dainton Report noted then that the drift from science and technology was occurring in several countries. The Report suggests that this drift 'may stem from very deep-seated causes relating to the nature of the appeal of science and technology to young people under many diverse educational and social conditions'. We shall also return to this point later.

The drift in Australia

An assessment of the nature and magnitude of any drift must approach the problem at both the secondary and tertiary levels. Table 3 considers the last year of secondary school in all states except Western Australia for which statistics were not available to me. It is necessary to consider a state-by state analysis because of differing matriculation courses and requirements, many of which have changed in the 1961 to 1967 period.

During this period, the number of seventeen year-olds in the five states, listed in Table 3, increased from 153000 to 192000. This represents an increase of 25% in the age group which may be considered to be eligible to undertake matriculation level courses as a possible prelude to possible tertiary studies. It will be noted from Table 3 that the proportion of candidates sitting for the whole matriculation examination in a particular state is increasing relative to the number of seventeen year-olds in the population. This increase has occurred *despite* the 25% increase in the available population and it is one of the root causes of the present crises in secondary education in Australia. It will also be noted that there are distinct differences between states with respect to the proportion of seventeen year-olds undertaking matriculation.

Generally speaking, the number of candidates potentially available to undertake tertiary courses in the sciences (i.e. pure science, applied sciences and science-based professions) is given to a reasonable approximation by the average number taking chemistry and physics at the matriculation examination. This is a crude approximation in some states since entrance requirements to tertiary institutions do not specify these two subjects and some students enter after having undertaken biology without chemistry and physics. Nevertheless, we are forced to use this as a guide to trends in the absence of more detailed statistics.

It is clear from Victoria and Queensland that the chemistry-physics group has declined in proportion to the total number undertaking the matriculation examination. This total number has doubled in this period in Victoria and more than doubled in Queensland. Consequently the chemistry-physics group has expanded numerically very greatly in this 1961-67 period but at about 85% of the rate for the total numbers of matriculation students. This is almos identical to the fall off in the chemistry-physics group in Scotland but the decline is far less than in England and Wales. You will recall that the Dainton Report judged the Scottish decline as not serious.

A second point is that the total numbers of students undertaking biology or chemistry-physics (assuming there is no double counting) is constant in Victoria and declining a little in Queensland. This factor is important in judging whether the final year students in secondary schools are able to avail

TABLE 3

Matriculation examinations by state from 1961 to 1967

Numbers of students taking science subjects compared to total numbers sitting for the whole matriculation examinations and total numbers of seventeen year-olds in the population

VICTORIA			1961	1962	1963	1964	1965	1966	1967
1	No. taking Chem-Phys / No. taking whole exam	%	28.3	28.2	26.2	26.5	27.2	25.2	25.0
2	No. taking Biology / No. taking whole exam	%	12.1	12.6	12.1	13.4	14.7	16.4	16.1
3	Sum (1) + (2)	%	40.4	40.8	38.3	39.9	41.9	41.6	41.1
4	No. candidates for whole exam		9720	11350	13534	15959	16836	18373	19353
5	No. candidates whole exam / No. aged 17 yrs in Vic	%	21.7	24.6	27.8	26.2	29.7	33.2	33.7
QUEENSLAND									
1	No. taking Chem-Phys / No. taking whole exam	%	65.9	65.1	66.1	64.6	60.5	59.1	56.1
2	No. taking other sciences* / No. taking whole exam	%	20.2	19.2	21.8	20.7	22.0	21.7	23.4
3	Sum (1) + (2)	%	86.1	84.3	87.9	85.3	82.5	80.8	79.5
4	No. candidates for whole exam		3613	4476	5806	6819	6621	7258	8254
5	No. candidates whole exam / No. aged 17 yrs in Qld	%	14.5	16.8	22.5	21.9	22.4	24.4	26.6
	*Zoology, Geology, Physiology								
SOUTH AUSTRALIA									
1	No. taking Chem-Phys / No. taking whole exam	%	57.6	58.8	57.1	56.6	57.0	66.5*	64.6
2	No. taking other sciences† / No. taking whole exam	%	22.2	23.2	25.3	24.8	24.3	38.5	35.6
3	Sum (1) + (2)	%	79.8	82.0	82.4	81.4	81.3	105.0	100.2
4	No. candidates for whole exam		5339	6462	7319	7804	8249	2876	3744
5	No. candidates whole exam / No. aged 17 yrs in SA	%	35.2	40.0	45.1	40.9	42.0	14.9	17.8
	*Matriculation based on fifth year of secondary school †Principally Physiology then Biology (1966 onwards), also Botany, Geology								
TASMANIA									
1	No. taking Chem-Phys / No. taking whole exam	%	106.0	93.7	82.1	74.1	75.7	76.6	71.9
2	No. taking Biology / No. taking whole exam	%	80.1	77.6	80.6	94.1	91.9	91.4	92.0
3	No. taking Geology / No. taking whole exam	%	35.8	21.8	18.6	16.0	16.0	18.7	17.6
4	No. candidates for whole exam		372	489	668	817	916	1036	1203
5	No. candidates whole exam / No. aged 17 yrs in Tas	%	6.4	8.5	11.5	10.9	13.4	15.5	16.7
NEW SOUTH WALES									
1	No. taking Chem-Phys / No. taking whole exam	%	78.2	83.0	79.4	78.7	75.1	(71.6)*	81.7†
2	No. taking Biology / No. taking whole exam	%	25.3	27.8	29.8	30.2	31.3	(20.7)	–
3	Sum (1) + (2)	%	103.5	110.8	109.2	108.9	106.4	(92.3)	81.7
4	No. candidates for whole exam		17064	18552	22427	24495	28742	(6895)	17857
5	No. candidates whole exam / No. aged 17 yrs in NSW	%	27.3	28.9	34.3	30.9	38.7		23.7
	*In 1966 most students were preparing for HSC exam in 1967 after six years of secondary school †Only the subject Science is available								

themselves of training in one of the scientific disciplines, regardless of any vocational prospect.

In South Australia where matriculation requirements changed in 1966 the evidence for a drift in the chemistry-physics group is negative. Not only does there seem to be no drift in the chemistry-physics group, but a very high proportion of all students were able to undertake at least one science subject.

Tasmania defies the statistician! Without statistics on individual students, it is difficult to determine the magnitude of any drift. I understand that many students take biology and/or geology with chemistry and physics so that addition of these categories is impracticable. The rise in the popularity of biology is apparent but since 1964, fairly stable enrolments seem to have been established.

Finally, New South Wales has, so readers of newspapers will recall, also changed its matriculation arrangements. Before that memorable day in 1966 there appears to have been only a small decrease in the proportion taking chemistry-physics. One notes also that the proportion undertaking at least one science subject, and now the integrated subject science, is quite high.

In summary, there is no evidence for a large drift away from the science-based courses at the matriculation level in different states. If there is a small drift at this level, it certainly does not merit immediate upheaval of courses—as been suggested in some quarters. Moreover it must be remembered that any small drift has occurred in a time period in which the number of seventeen year-olds has risen sharply and the proportion of these seventeen year-olds undertaking matriculation studies has also increased sharply.

Now it might be supposed that the matriculation year may not reveal the drift and that this would only appear at the tertiary level. Immediately a basic problem arises in that although firm statistical information is available from universities, this information has been lacking until quite recently for

TABLE 4
All new Bachelor Degree students (F/T, P/T and Ext) by area of study at Australian universities 1955-66

	1955	1957	1959	1961	1963	1966
SCIENCES[1]						
(a)	2615	3556	4653	6791	7555	9466
(b)	45.2	48.0	46.1	51.2	47.9	42.7
(c)	2.15	2.75	3.39	4.63	4.34	4.58
ARTS[2]						
(a)	2218	2469	3.564	4115	5241	8255
(b)	38.3	33.4	35.3	31.0	33.3	37.2
(c)	1.83	1.91	2.60	2.80	3.01	4.00
SOCIAL SCIENCES[3]						
(a)	958	1376	1870	2359	2960	4464
(b)	16.5	18.8	18.6	17.8	18.8	20.1
(c)	.79	1.06	1.36	1.61	1.70	2.16
TOTAL NEW ENROLMENTS	5791	7401	10087	13265	15756	22185
18 yr olds in population as at June 30	122449	129459	137158	146800	174200	206600

[1] Includes Science, Medicine, Engineering, Agriculture, Veterinary Science, Dental Science, Architecture, Forestry and other subjects such as Optometry

[2] Includes Arts, Music, Divinity, Oriental Studies and related subjects

[3] Includes Law, Education, Commerce/Economics, Agricultural Economics, Psychology Social Work and related subjects

(a) New Bachelor Degree students

(b) (a) expressed as a percentage of total new enrolments

(c) (a) expressed as a percentage of eighteen year-olds in population

TABLE 5
Bachelor Degree enrolments in various faculties 1961 and 1966-68, in Australian universities

FACULTY	1961 No.	%	1966 No.	%	1967 No.	%	1968 No.	%
Arts*	14240	30.9	29028	38.7	30034	38.7	32334	39.0
Law	2395	5.2	3899	5.2	4213	5.5	4640	5.6
Economics/Comm	5664	12.3	9234	12.3	9960	12.8	10962	13.2
Science	7696	16.7	11793	15.7	12411	16.0	13443	16.2
Applied Science	1914	4.1	1405	1.9	1190	1.5	1243	1.5
Architecture	1240	2.7	1973	2.6	1963	2.5	2008	2.4
Engineering	4813	10.4	6959	9.3	6746	8.7	6996	8.4
Dental Science	812	1.8	1177	1.6	1163	1.5	1102	1.3
Medicine	5137	11.1	5698	7.6	5886	7.6	6254	7.6
Pharmacy	642	1.4	921	1.2	856	1.1	709	0.9
Agr Science	1003	2.2	1296	1.7	1339	1.7	1486	1.8
Vet Science	530	1.1	987	1.3	1058	1.4	1015	1.2
Other	46	0.1	667	0.9	734	0.9	725	0.9
TOTAL	46132	100.0	75037	100.0	77553	100.0	82917	100.0
Total Sciences		51.5		42.9		42.0		41.3

*Includes Education, Music and Social Studies (AUC Report 1969)

senior technical colleges or, as most are now designated, Colleges of Advanced Education. This is especially difficult in the state of Victoria where substantial numbers of scientists and engineers have been trained to professional levels in the larger Colleges of Advanced Education. Consequently long term trends are difficult to assess on a national basis.

Table 4 considers new enrolments in Bachelor degree courses in Australian universities. The total new enrolments almost quadrupled from 1955 to 1966 during which time the number of eighteen year-olds rose by 170%. It is seen that the number of new enrolments in all the sciences expressed as a percentage of total new enrolments ((b) in Table 4) rose to a maximum of 51.2% in 1961 and fell to 42.7% in 1966. In the same period, the corresponding percentage for arts has fluctuated whereas the percentage for the social sciences has risen steadily. Here seems to be the first evidence for a drift from the sciences.

Two matters need to be considered to set any such drift in perspective. Firstly, which year is to serve as our baseline for comparison? The drift is small if 1955 is used whereas it is significant if 1961 is used. Secondly, the percentage of new enrolments in the sciences compared to the eighteen year-olds in the population has risen fairly steadily over the decade in question ((c) in Table 4) despite a very large population increase in the relevant age group. We might also note that the drift that has occurred is relatively to the social sciences rather more than to arts.

These statistics need to be considered in a little more detail. Table 5 considers the pattern of new enrolments in Bachelor courses according to Faculties or broad subject disciplines. When we talk about the social sciences, the numerically large groups are commerce/economics, then law and to a lesser extent education. Of these law is increasing most rapidly. In the sciences, the largest faculties are medicine/surgery, engineering and science itself. The most important feature of these enrolment figures is that whereas steady increases occur between 1963 and 1967 in all the major arts and social sciences areas, this is not so in the sciences. Science itself has increased significantly but medicine is stationary as are dentistry, surveying, architecture, agricultural science and veterinary science. Engineering is increasing somewhat slowly. The stationary enrolment figures reflect to a large extent the effect of quotas applied by the largest universities in these areas. It is in these vocationally directed sciences that any drift from the sciences is involved.

This is emphasised again in Table 5 which is taken from the Australian Universities Commission Report for 1969, tabled in the Commonwealth Parliament recently. This Table summarises the total enrolments in various Bachelor degree courses from 1961 (the peak year for the sciences, see Table 4) and 1966-68. These total enrolment figures may not be as sensitive to short term shifts as the new enrolment figures, but both sets of figures run in very close parallel.

Table 5 shows that the percentage enrolment in science is virtually constant. There are small reductions in almost all of the other sciences although since 1966 there is little change. Once again the drift from the sciences is located in the applied sciences and the professional courses; it does not occur in B.Sc courses. This conclusion is based moreover on 1961 as the peak year. If 1955 were used as the base, the drift would be much smaller.

One can only argue that there has been a real drift from pure science if one proposes the following hypothesis: 'Since the applied sciences and professional sciences have had their enrolments restricted by quotas, then students rejected from such courses would have taken up science as a second choice; hence the science numbers should have risen more sharply than they have done.' In my opinion this is a somewhat doubtful hypothesis and it could only be answered by detailed statistics on individual students. My involvement with selection in two universities suggests to me that some students rejected from quotas go elsewhere rather than to the universities. For example they may prefer to take up courses at Colleges of Advanced Education and others, rejected from a professional course such as medicine, undertake law rather than another science.

One final test for a drift may be made with degrees awarded by Australian universities. Table 6 shows that between 1955 and 1967 the number of Bachelor degrees awarded trebled in the sciences but the number of degrees in the arts and the social sciences approximately quadrupled. Consequently the percentage of science degrees fell from 56.2% to 48.4%. Once again this will be reflecting to a large extent the lack of expansion of enrolments in the applied sciences and scientific professions. The relative fall is greater than the fall in enrolment and it may reflect the fact that it is more difficult to undertake part-time studies in the sciences. Thus a student failing in one or more subjects in the sciences may tend to withdraw more frequently than his counterpart in arts. Likewise the increase in social science degrees is relatively less than in arts, despite a similar enrolment pattern. An alternative hypothesis would be that the failure rate in arts is less severe than in science or social sciences but full data are not available.

In terms of natioanl output of qualified scientists and engineers, the new Colleges of Advanced Education make a significant contribution. In 1960, 864 B.Sc graduates qualified and 182 diplomates in science; in 1966 this rose to 1979 B.Sc and 261 diplomates. In 1960, 523 B.Eng graduates qualified and 555 Dip.Eng; in 1966, there were 913 B.Eng and 768 Dip.Eng. The greatest numbers of diplomates are trained in Victoria. These numbers do not affect, however, the conclusion that there is a relative fall in the proportion of university graduates in the sciences.

So far, all the arguments concerning possible drifts from the sciences have been expressed in terms of quantity. What is not known is whether the relative quality of the students of the sciences has fallen. This drift in the output of graduates may be a sign of this but the argement is tenuous.

In summary, my findings are that in Australia there is only a very small decline in the proportion of students at the matriculation level undertaking courses directed to the sciences; the decline in the proportion of new enrolments in the sciences occurs primarily in applied sciences and professional science courses, for which entrance is restricted; there is a decline in the proportion of graduates in the sciences, almost certainly in the applied and professional fields. The magnitude of these relative reductions are certainly not as great as in England and Wales. The output of graduates is increasing faster than the rise in the teenage population.

We may now enquire as to possible causes of these drifts and their possible consequences.

CAUSES OF THE DRIFT

Increasing student numbers

The tendency to undertake longer education is an international phenomenon. In Australia it has some consequences which probably have affected the drift. As an example consider employment in a wide range of commercial undertakings such as banks and

TABLE 6

Bachelor Degrees awarded by area of study at Australian universities 1955-67

	1955	1957	1959	1961	1963	1965	1967
SCIENCES[1]							
(a)	1667	1674	1914	2289	3358	4111	5029
(b)	56.2	55.3	52.9	54.6	54.2	52.5	48.4
(c)	1.42	1.39	1.46	1.64	2.30	2.66	2.76
ARTS[2]							
(a)	863	825	1140	1223	1824	2409	3510
(b)	29.1	27.3	31.5	29.2	29.5	30.7	33.8
(c)	.74	.69	.87	.88	1.25	1.56	1.92
SOCIAL SCIENCES[3]							
(a)	437	526	561	679	1011	1319	1854
(b)	14.7	17.4	15.5	16.2	16.3	16.8	17.8
(c)	.37	.44	.43	.49	.69	.85	1.02
TOTAL DEGREES	2967	3025	3615	4191	6193	7839	10393
22 yr olds in population as at June 30	117167	120047	130732	139400	145700	154500	182400

[1] Includes Science, Medicine, Engineering, Agriculture, Veterinary Science, Dental Science, Architecture, Forestry and other degrees such as Optometry

[2] Includes Arts, Music, Divinity and degrees in related areas

[3] Includes Law, Education, Commerce/Economics, Agricultural Economics, Psychology, Social Work and degrees in related areas

(a) Bachelor degrees

(b) (a) expressed as a percentage of total degrees awarded

(c) (a) expressed as a percentage of 22 year olds in population

TABLE 7

New Bachelor students in all Australian universities classified according to sex

	1963	1964	1965	1966	1967*
Male	11338	12885	14135	15177	14097
Female	4379	5454	5927	7008	6217
Total	15717	18339	20062	22185	20314
Percentage Female	27.8	29.7	28.8	31.5	30.7

*Figures influenced by changes in NSW matriculation

TABLE 8

Percentage of females enrolling as new Bachelor students in Australian universities (classified according to faculties)

FACULTY	1964	1967	FACULTY	1964	1967
Science	23.6	24.5	Sciences (overall)	17.2	17.0
Engineering*	0.4	1.0	Law	12.7	13.4
Dentistry	13.8	16.4	Education	46*	50.7
Medicine	20.9	19.1	Comm/Econ	13.1	11.5
Pharmacy	49.7	41.4	Social Sciences (overall)	14.4	19.6
Agric Science*	10.9	8.7	Arts	56.4	51.9
Vet Science*	14.5	11.5			
Architecture*	14.4	7.5	FEMALES (overall)	29.7	30.6

*Small numbers of students are involved

insurance offices. Whereas a decade or so ago, the intermediate certificate awarded at fifteen to sixteen years sufficed, now entrance is required after the next year, often called the leaving year, and 'matriculation standard is to be preferred'. This is an increasing requirement imposed by employers. Now I would like submit that young people proposing to enter such employment would be less likely to undertake the more specialised science courses in the last two years of secondary school. The effect of this would be to reduce the proportion of students counted in the science group.

Changing sex patterns

The proportion of female students entering universities is slowly rising, as shown in Table 7. Whilst this has undoubted influence upon university morale, it also affects the pattern of student enrolment. The great majority of females enter the very large arts faculties in universities. Table 8 shows that more than half of all arts new enrolments are females, although catastrophically for our arts colleagues, this proportion is falling—probably as a result of increasingly competitive entrance requirements. The pattern of female enrolments in the applied and professional sciences is interesting in that only pharmacy is seen as a 'proper' vocation for women. Science itself is not too unattractive whilst engineers will note that the female proportion is doubling in just under three years!

The overall effect of this rise in female students, and their predisposition to arts, is to cause a reduction of approximately one percent in the proportion of new enrolments in science to total university enrolments, e.g. line (b) of Table 4. The predisposition of girls towards arts has often been attributed to inadequate science teaching resources in girls' schools. However it is intriguing to me that in some high schools, where boys and girls are taught by the same teachers, the same predisposition seems to occur. This suggests to me that the cultural background of boys and girls is a very significant factor in these preferences.

New career opportunities

Two decades ago, the vocational prospects for graduates in social sciences were not generally considered good but in recent years this situation has improved. Greater emphasis is being placed on management skills and many students regard university courses in commerce, economics and now law as preparation for new careers in the commercial world. The consequence has been a significant rise in enrolments in the social sciences. Whereas before the sciences offered the most obvious entre to a wide range of vocations, now social sciences offers competitive possibilities.

Disenchantment with science

It is often contended that our youth has become disenchanted with the material progress attributed to science and that it is turning instead to studies in the arts and the social sciences in the hope that they will be equipped to deal with the human problems which are at the basis of contemporary difficulties. As the late Professor Rubbo said last October:

What we are suffering from in our highly developed state of technology is not so much the problem of controlling our environment and searching for control of outer space, but of controlling our own human relationships. What is really facing the modern world today is to make sure that science is not going to be misused in the service of man.

It is certainly true that each development in science paradoxically offers man the alternative prospects of constructive and destructive ends, of freedom from disease or of biological warfare. What does not seem to be established is whether this is a real or a rationalised influence on any drift from the sciences. There seems little doubt that our students in the sciences are vitally aware of these moral and ethical issues. For example, at a recent Junior ANZAAS discussion in Adelaide, secondary students quizzed the panel of scientists almost wholly on issues such as the ethics of space expenditure versus hunger, conservation, pollution and religion. But does it follow that another group of students was deterred from the sciences by these same problems? The question is surely open. It may be argued that since the young are curious, they will wish to learn of the background to these issues and thus be able to participate more effectively in the community.

Uninspiring science courses

Science teachers will have noted, with a sigh, the clarion call by the Dainton Report for 'breadth, humanity and up-to-dateness in science courses'. I have endeavoured to show before that drifts from the sciences in Australia are not as serious as is often suggested and that social and demographic causes outside the control of a science teacher are probably contributing to this drift. Therefore I do not see this drift as an excuse for flagellation of the science teacher. It is true that courses can be improved, and will in the nature of events, continue to improve in an evolutionary manner. I do not see the relatively minor drift as an excuse for revolutionary educational action.

Moreover it is useful to consider the corollary of the contention that any drift from science is due to

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uninspiring teaching. The corollary is that in halcyon days of yore when science was 'attractive', the teaching was inspiring. Two decades ago, when I was undertaking my science course, there was tremendous emphasis on rote learning, practical courses were puritanical and I do not consider that these were inspiring courses, despite able teachers. It is my contention that students of my era undertook science courses because the pervading social ethos was that 'one did a course for a career and everyone must have a career'. At that time there was considerable personal and community vocational motivation for vocational training and this was reflected in enrolment patterns.

The advocates of more and more scintillating courses have been likened to the alchemist and his apprentice. If only the alchemist could obtain a skilful enough apprentice who would stir his broth properly and rapidly enough, then the problem would be solved. There does not seem to be evidence that stirring of the eucational broth with new up-to-date courses has affected any drifts in science enrolment in the last few years. Consideration of the matriculation statistics in Table 3 and the years at which new courses in physics and chemistry were introduced, reveals no arrest in any drift. There are reasons to believe that these new courses can enthuse and enlighten students who have chosen to enter the science stream but I do not see evidence that the courses cause a reversal in enrolments.

I might also comment at this point on the frequent practice, in discussions on this matter, of singling out a particular year or a particular course for criticism. I believe that courses cannot be considered in isolation and that any supposed deficiency in a student completing a course of study must be attributed to his overall education. For example, it is often asserted that a science specialist lacks a feeling for the arts since in his matriculation year he does almost all science. If this deficiency did exist, then it is a criticism of his twelve years of primary and secondary education which includes a wide range of courses including literature, history and languages. Likewise it is unrealistic to criticise, in isolation, a matriculation course as in the assertion that 'students lack an appreciation of scientific theories'. This is a deficiency of five or six years of training in secondary science in which a single course can only assume a proportion of the blame. Conversely it is unrealistic for curriculum reformers to expect a single subject to develop every human virtue from intestinal fortitude to aesthetic appreciation. It is the quality of the overall education which must be considered and reassessment of this is what our youthful critics of the present educational system are demanding.

Difficulty of science courses and the knowledge explosion

We all tend to judge the present day from anecdotal experiences. Parents frequntly remark that a course 'must be getting harder because we did not meet that work until three years later'. This is an understandable response but, in the case of science, it neglects the role of principles and laws in codifying the exponential growth of facts.

Sir Peter Medawar, Director of the Institute of Medical Research in England, has said:

The ballast of factual information, so far from being just about to sink us, is growing daily less. The factual burden of a science varies inversely with its degree of maturity. As a science advances, particular facts are comprehended within, and therefore in a sense annihilated by, general statements of steadily increasing explanatory power and compass—whereupon the facts need no longer be known explicitly i.e. spelt out and kept in mind. In all sciences we are progressively relieved of the burden of singular instances, the tyranny of the particular. We need no longer recall the fall of every apple.

But of course the increasing introduction of concepts and principles is intellectually more demanding than the recall of factual information. This is the area where measures of conceptual ability with maturation are so important; an area where Professor Fensham is so concerned. Moreover the other requirement is that students have a proper appreciation of the nature of scientific observations and the relationship between fact and theory. Clearly this aspect must precede the more theoretical course and it must always be an important feature of general science in the mid-secondary schools.

The other aspect of judging the difficulty of a course is the standard of achievement demanded in a course. This involves the interaction of professional and general educational aims which I shall touch on subsequently.

Summarising then, the probable contributory causes of the relatively minor drifts in Australia are: the increase in student numbers, increases in the proportion of females, and new alternative careers outside science. The alleged disenchantment with science I consider not proven and I do not accept that the latest courses in secondary school science are uninspiring, as distinct from the conditions under which pupil and teacher labour.

Drifts from science teaching

I come now to what I now regard as the most alarming and the most dangerous drift of all. We saw before that the national output of science graduates is generally keeping pace with the overall Australian population increase and the increasing proportion of students taking higher education. It might be concluded that there is no immediate cause for concern, in that the national supply of science teachers would be adequate. The blunt fact is that the proportion of science graduates embarking on science teaching as a career is falling sharply. Science teaching as one vocational career for science graduates is declining in its relative attractiveness.

An example, which is probably no worse or better than in other states, is provided by the South Australian situation. Despite the opening of a second teachers' college, associated with a South Australian university, the enrolment of prospective science teachers has declined from 166 in 1964 to 123 in 1969. In the same period, the percentage of science enrolments compared to the total new enrolment in the teachers' colleges has declined from 51% in 1964 to 33% in 1969. Within a fixed quota of new students in the Faculty of Science of the University of Adelaide, the percentage of prospective science teachers has declined from 40% to 23% in four years. This decline cannot be a product of any drift from science because in all these years no qualified student has been rejected. I understand informally that similar serious declines have occurred in other states. When this decline is coupled with an increasing tendency of the remaining student science teachers to prefer biological sciences, the prospect in the next few years is grave. The qualified optimism of my earlier remarks may be rapidly reversed.

There is an urgent need to establish the basic causes of this disaffection with science teaching as a professional career for science graduates. The most obvious comment is that science teachers are observed daily by their pupils who can extrapolate their observations to form a fairly accurate picture of science teaching as a career. They no doubt observe teachers who carry as heavy a form teaching load as any on the school staff, teachers who face constant pressure to remain up-to-date with subjects undergoing exponential growth, and teachers who need to innovate continuously to mount practical courses when much of this work could be undertaken by supporting rechnicians. Little wonder that negative attitudes develop in students' minds towards science teaching. This negative attitude was highlighted recently on the ABC when the plight of a Queensland M.Sc graduate in marine zoology was mentioned. After twelve months he had only been able to secure employment as a labourer in a steelyard. When asked why he did not take up school teaching, he said he 'did not wish to perpetrate the same old things year after year and anyhow, your skills are not used'.

It seems quite apparent that science teachers are not employed in science teaching in the same manner as are other science graduates in government and commerce. Unless conditions are comparable, recruitment will be fruitless. Quite apart from the question of salaries, the attraction of teaching to graduates can be realistically enhanced by measures such as the following:

1 increased ancillary staff to attend to the prepatory work for practical classes which are as diverse in character in small schools as they are in large;

2 relief from extraneous school duties which would never be undertaken by graduates elsewhere;

3 the opportunity for younger graduates to teach senior classes from time to time (this often emerges as a frustration for graduates of recent training);

4 sufficient spare time for the graduate science teacher to undertake minor investigations in his school laboratory, e.g. an afternoon a week;

5 guaranteed regular arrangements for re-training. The IUPAC committee on Chemical Education recommended in Prague in 1967 that each graduate teacher should be re-trained every five years as a minimum for four weeks but preferably up to three months in duration.

The issue of re-training is essential if teachers are not to drift away from science. Otherwise an arid presentation of subjects will develop. If a sense of vitality is to be infused into a subject, a teacher must have the opportunity to consider regularly the general developments in his speciality. This cannot come from swift readings of *Nature* or *Scientific American*. It only stems from sustained consideration of his subject which can be offered by inservice courses designed specifically for his needs.

Now it may be suggested that many of these measures are impossible in the present staffing situation. Yet unless the vicious circle is broken the science teaching position will progressively worsen. I believe that there is a number of science graduates potentially available in the community which could be attracted into the teaching profession if a realistic allowance for outside experience is made in assessing salary. A flexible attitude to salary structure is a problem which has to be faced by both governments and teachers' organizations alike.

Drifts from the scientific disciplines

For some decades, there has been a rather monolithic view of scientific disciplines. There was a clearly defined discipline called Physics which had little interaction with another discipline called Chemistry. One studied within such a discipline, a sequence of clearly-defined topics. It was considered that all physicists must study and appreciate the same aspects of the discipline.

The last two decades have highlighted the increased interdepencence of scientific disciplines and this has thrown up different needs in courses for new graduates. A potential graduate expecting to be trained in a particular discipline must also be trained to a high level in related fields which would previously be regarded as distinct disciplines. Paradoxically, study in greater depth must be accompanied by study in greater breadth. A student may need to be able to study aspects of more than one supporting subject in order that a major speciality subject be supported adequately. Even within a major discipline, such as geology, there is a need for different combinations of supporting subjects, such as geology, there is a need for different combinations of supporting subjects as in the training of a geochemist (a geologist strongly trained also in aspects of chemistry) and a geophysicist (a geologist trained also in aspects of terrestrial physics). In these circumstances traditional subjects cannot serve a satisfactory dual role to support both specialist graduates in that subject and graduates in other specialities requiring training in specific aspects of that subject.

Some Australian universities are therefore reconsidering their science course structure, especially in the later years of the course. The aims are to achieve flexibility in the proportions of subjects, to provide specific courses which can be combined in different ways to support a major speciality and to bridge interdisciplinary barriers.

At Adelaide University, as an example, a 'unit-course structure' was initiated in 1968 to meet these changing needs. In place of the single traditional third-year subject, a department now offers for study at least six smaller courses known as units. These unit courses are each equivalent in content to one-half of one term's work in the earlier third-year subject. A student wishing to continue with two equal subjects in his third year would therefore undertake six unit-courses from each of two departments.

Additional flexibility is introduced both by some departments offering more than six-unit courses and also by allowing students to undertake either eight units from one discipline with four units from another or six units from one discipline, four from another and two from a third. Each combination of unit-courses is designated as a distinct subject. In previous years the departments participating in this scheme offered a total of 10 subjects at the third-year level but now a total of 39 subjects, based on unit-course combinations, are available for study. A student should therefore be able to select a course combination tailored specifically for his particular future needs. Provision is also made for a student to incorporate some elective unit-courses within a combination, always subject to approval that these elective units are appropriate to his academic career.

A few examples may illustrate the flexibility now available in the third year. A potential zoologist, interested in the molecular basis of biology, may now take a course consisting of six zoology units with four units in biochemistry on Genes and Proteins combined with a course on Cells and Embryos provided jointly by Botany and Zoology. In early years a student had to decide either for a full third-year course in biochemistry or one in botany. Now he may undertake a course which includes the most appropriate topics. The unit-course on Cells and Embryos is an interesting development in that the basis of this course is the scientific content and not a particular departmental division; previously combination subjects between departments were almost unknown at third-year level but now interdisciplinary subjects may be readily presented.

A potential geochemist now has the choice between either a course based equally on geology and physical and inorganic chemistry or a course with eight units of geology and four related units in physical and inorganic chemistry.

A potential chemist interested in the physiochemical properties of very large molecules in biological systems may now undertake four units in related topics in organic chemistry with two units on enzymes presented by biochemistry. Previously he would have been faced in his third year with a choice between organic chemistry and biochemistry. Another potential chemist may decide either on the biochemistry units on Genes and Proteins or on units in Mathematics which are most appropriate to his needs in his major chemistry units.

I believe that variants on this course structure will become more and more common throughout Australia. It is a step beyond the well-known US system since interdisciplinary courses are involved and it is a drift which I applaud.

It might be considered that this argues strongly for 'integrated science' at the secondary level. I am not persuaded on this point since it is important to note that this elective unit course approach has been introduced only after the principles of the subject are well established. Moreover an administrative decree does not remove the very real differences of conceptual approach between a 'macro' science, such as geology and parts of biology, and a 'micro' science, such as chemistry in which one thinks largely in terms of atomic dimensions. These are important conceptual differences which should be recognized in course structures.

Drifts in educational philosphy

In recent years, there has been an important shift in educational philosophy in which the earlier vocational end of education is steadily giving way to a re-statement of education as the realisation of self-fulfilment for the individual. Like motherhood, all tend to agree that this is an excellent and admirable state. But also like motherhood, this movement has its growing pains. Dr Cohen has drawn attention to the growing clash between convergent and divergent approaches to science teaching. The divergent approach tends to emphasise the self-discovery aspect of science, and this has its origins in the heuristic philosophy of some sixty years ago with its emphasis on personal experience. On the other hand, the convergent approach emphasises the importance of scientific laws as giving meaning to apparently disconnected observations, and sets high value on deduction. The divergent approach has been associated by philosophers with empiricism whereas the convergent approach is associated with rationalism. Increasingly professional scientists, who profoundly influence technology and in turn are subject to demands by technology, are associated with the convergent, rationalist approach.

The present courses in science contain elements of both approaches. In Dr Cohen's opinion the influence of the convergent approach is summarised by the statement of the student: 'I came, I saw' I concurred'. Many would see out most modern science courses as being too restrictive on the imagination and in reducing personal excitement, in that students must conform within certain basic laws and principles. It is suggested that potential teachers, who need to be sympathetic characters who value human relations, are repelled by this characteristic of secondary school science and therefore they elect to study arts-type subjects.

Yet to object to this aspect of science courses is to object to science itself. The last one hundred years has seen the steady establishment of basic laws upon which the practitioners have reached general agreement. No longer do scientists question, say, the law of conservation of energy; scientific arguments proceed on that assumption. Indeed the remarkable progress made in science has largely arisen from the substantial agreement upon what is basic; from these points science proceeds to probe further into understanding the frontiers of the subject. It is essentially a convergent approach. Moreover the internationalism of science imposes a fair degree of equality in the standards of achievement at which it is judged that a graduate is equipped to practise a scientific profession. This point is the key to the conflicting demands of standards expected at the secondary and at the tertiary levels. It is often forgotten that teachers of science at the tertiary level are under great pressures to adjust continually to the growth in science and to the need to qualify graduates equipped to practise contemporary science.

At present in Australia this professional stage is judged to occur at the Bachelor Degree level. The community allows three years of tertiary study to attain this professional level. Little wonder that increasing professional demands are made at the final secondary level in science courses. Simultaneously our educational philosophy is drifting away from the profession-oriented courses in science. The vital problem for teachers, secondary and tertiary, and curriculum innovators is to reconcile these approaches. It is clear that the divergent approach is appropriate to the early years of science study and the convergent approach to the later professional years. But where should the emphasis change? We have drifted into this dilemma in science education and only detailed and frank discussion on all sides can hope to resolve the problem.

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