Special Paper

A STUDY OF PROCEDURES OF SELECTING AND CHANNELIZING SCIENTIFIC TALENT FOR RESEARCH AND DEVELOPMENT. PART II

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1. Introduction

The teaching of science at our universities has a reasonably long history at the undergraduate and even the postgraduate level. However, the applications of science in the shape of technology and inventions are hardly three decades old, because this aspect dates back to 1939 when World War II began. This forms part of the world-wide shift in emphasis from the humanities towards science and technology, and we find a larger proportion of Pakistani students going into the scientific fields. While this is encouraging in itself, a very real problem is posed by the fact that the student taking up science at the intermediate and undergraduate level does *not* always have a reasonable aim and even, in some cases, may *not* posses the necessary capabilities essential for a useful output during his productive years after he has finished his academic phase.

To illustrate with figures from Pakistani universities, it is known that in the early 1950's all our universities put together produced something like 100 M.Scs every year. Today, this number has gone up tenfold, and a thousand fresh M.Scs leave the universities each year. Of these, perhaps a third find employment in industry, and another 300 in universities and various Government or semi-Government scientific institutions. This leaves upwards of 300 unemployed for a year or more, and it is therefore desirable to consider ways and means of rectifying this waste resulting from maldistribution of training and talent.

In an earlier paper,[1] dealing with certain improvements in our interview and selection procedures, it was shown (a) that it is possible to obtain a stable evaluation or grading of interviewed candidates to within $\pm 3\%$, provided that each member of a board of six gives his independent grading, and (b) that, although there is only a 20% correlation between this evaluation for any one category of post and the mean academic grades obtained by the candidates, nevertheless certain general relationships can be obtained between the candidates' academic grades and the level he is likely to attain in his profession. From an analysis of the 1967 data for class II officers and three categories of class I officers (R.O., S.R.O., and P.S.O.) in the Defence Science Organization and the Central Laboratories of the P.C.S.I.R., it was found that the academic grades of S.R.Os and P.S.Os are in fact markedly higher than those of the lower categories. This is shown in the histograms (reproduced in Fig. 1(a)) of population versus grade index, obtained by giving 1 unit for each II division and 2 units for each I. As a corollary to this, certain criteria for distinguishing between potential research scientists and the technician type were considered. It is the purpose of the present paper to (a) extend these observations to higher categories of research scientists, as also to include some data on research output, and (b) to study in more detail the region between grade index 4 and 3, *i.e. at, and just below* the second division level in the various examinations, with a view to closely defining the criteria for career planning at an early stage, and to prevent undue frittering away of scientific training on those unlikely to provide a useful return.

2. Additional Data on Heads of Research Divisions and Directors of Laboratories

The first step is to extend the histograms of Fig. 1(a) to some higher categories of scientific officers. The two grades next above P.S.O. (Principal Scientific Officer) are Head of Research Division and Director of Laboratories. Data are available for 1967 on four persons in the first category, and four in the second. While these numbers would ordinarily be too few for a detailed analysis, nevertheless it is worthwhile plotting their *combined* histogram, because this is expected to be very narrow (extending perhaps from grade index 5 to 8) in view of the trend observable in Fig. 1(a). Accordingly, Fig. 1(b) (top) shows the combined histogram* for these two categories, which is a little narrower than that for P.S.O's and has a mean index of 5.8. We may also now examine the separate histograms for Heads of Research Division and Directors, as plotted in the middle and lower half of Fig. 1(b); these fit in with the general trend, the mean grade indices

*Of these 8 individuals, one with a grade total of 5 up to the B.Sc. went straight on to do his Doctorate, and so his M.Sc. grade has been estimated at $1\frac{1}{2}$, giving him an overall index of $6\frac{1}{2}$. He has therefore been shown as 1/2 against index 6 and1/2 against index 7 in Fig. 1(b).

for Heads of Division and for Directors being 5.8 and 5.9, respectively. Also, it is interesting to observe that these histograms are only slightly asymmetric about their centroids.

It is now possible to complete the representative graph for seniority or status of scientific post versus the mean grade index, as shown in Fig. 2, where the new data for Heads of Division and Directors are plotted as solid circles. With the addition of these two points, the complete graph shows clearly the relatively smooth increase in grade index between the two extreme values of 3.8 at the lower end and approximately 6.3 at the upper end. The upper limit of 6.3 is being approached asymptotically, and shows that those with mixed I and II division careers are best. The lower extreme value (3.8) is also quite sharp and definite for Research Officers and the lower (Class II) posts for fresh M.Scs/B.Scs, thus indicating that this can be taken as a lower limit for any career in scientific research. Since the half-value width of the corresponding histograms in Fig. 1(a) is about ± 0.9 unit of grade index, we conclude that the lower limit for selecting scientific officers can be set at 3.8 ± 0.9, i.e. between 2.9 and 4.7 grade index. Also, we see that the histograms of Fig.1(b) fall to zero below a grade index of 4, while that for P.S.Os has about 15% population below this index, thus indicating that an M.Sc. with a grade index below 4 has *no* chance of getting to the top-most posts, but does have a small chance of reaching the Principal Scientific Officer level. This involves two promotions from Research Officer, on the basis of research output, and may therefore be accepted as a reasonable *minimum criterion* for a satisfactory career in scientific research. Thus, the cutoff line is located between grade index 3 and 4, and we should examine in detail the academic behaviour of those who get a grade index of 4.

3. Relation of Output with Grade Index

Further confirmation of these findings is obtained by making an analysis of the research output of some of the senior officers over a period of ten years. This period is used in order to smooth the effect of any periodic changes in the activity level of any one individual. We select for this analysis a dozen persons who were P.S.Os in 1967 in the D.S.O. and the Central Laboratories of the P.C.S.I.R. These persons who did their M.Sc. between 1944 and 1953 have all been promoted to P.S.O. during the period 1962 to 1967, and we examine their output during the ten years from 1955 to 1965. The output can, as a first approximation, be measured by the number of research publications plus patents and major technical reports, as available in the reports and records of P.C.S.I.R. and D.S.O.

A synopsis of these data for this sample of 13 P.S.O's is given in the table below, and the mean output corresponding to each grade index is plotted as a histogram in Fig.3. Clearly, the highest output comes from the persons with grade index 4 to 6, which apparently gives the best combination of qualities for research work. Thus, we must make a further examination of persons having grade index 3 and 4.

Grade index	3	4	5	6	7	8
No. of persons	2	1	3	4	1	2
Total output 1955–65	3+13	13	9+6+6	25+10 4+21	4	15+9
Mean output/ P.S.O.	8	13	7	15	4	12

Grade index 4 is made up mostly of persons getting four second divisions, with a slightly smaller proportion of those having one third compensated by a first division (i.e. I, III, II, II or various permutations). While Fig. 1 shows that such persons have a small chance of going up to Principal Research Officer, Fig. 3 indicates that those who do get this far have a respectably high output; so this category may be taken in research *if* they show an exceptional aptitude for research work.

4. Early Prediction of the Borderline Cases

The problem now resolves itself into one of spotting *fairly early on* in their academic careers those students who are going to end up with a grade index of 4 or less, and diverting them generally towards activities other than pure or applied research, *unless* they at the same time demonstrate an unusual aptitude for scientific research. Doing this at the B.Sc. level is fairly easy, because two thirds of the student's university career is behind him, but if this can be done early enough, say at the intermediate level just before the student is due to start an honours university course, then the diversion from a science degree towards a technical course can be made *without any loss* in years of study. Accordingly, we first examine this possibility by using as a representative sample the class II (i.e. junior) officers in the Defence Science Organization and the Central Laboratories of the P.C.S.I.R. numbering 114 altogether, in 1967.

At the intermediate level, the borderline cases would be those with two second divisions or with one first and one third, which would yield a grade

index of 4 only if they repeat this performance in the B.Sc. and M.Sc. The lower category with one second and a third up to the Intermediate level rarely works up to grade index 4, as can be seen later. (It is important to remember that, while history does have examples of a few persons graded as mediocre who turned out brilliant like Pasteur or Darwin, the *below-average* student *never* gets anywhere at all.) Out of the above-mentioned total sample of 114, there are 27 who got a II division in the Matric followed by a II in the Intermediate (I.Sc.), and 8 with a I compensated by a III division, making 35 in all. The complete academic grades of these particular 35 junior officers are collected in Table 1, together with the overall grade index for each person.

The complete histogram of the grade indices attained by these 35 persons is shown in Fig. 4(a), and two facts stand out, namely (i) that almost 60% have a grade index of 4, and (ii) that a sizeable fraction of these 35 persons have attained a grade index of 5 in their academic career, thus confirming that these borderline cases can yield some good (research) scientists. Since the sample has an effective index of 2×2 up to the I.Sc. level, it can be concluded that the basic pattern has more or less stabilized at this stage, and the two grades up to the Intermediate level do give a 60% reliable prediction of the ultimate total academic grades. There is no great difference in this respect between those with two II divisions and those with a I and a III division, because, in Table 1, there are 8 examples of the latter, six of whom end up with a grade index of 4. (In fact, these persons with a III division compensated by a I division may even end up a trifle better than those with two II divisions).

5. Suggested Processing of those with (II+II) or (I+III) at I.Sc. Level

Out of those in this category going on to B.Sc. and M.Sc., about 85% end up with a grade index of 4 or less, so that some planners might be tempted to reject this lot out of hand, in view of the large numbers of higher-grade M.Scs now available. However, in fairness to the remaining 15% who do go on to improve their grades to 5, as well as those with grade index 4 but having a special research aptitude, it would be worthwhile devising a way of picking out these few possibles for a scientific career. One way would be to give all those with (II+II) or (I+III) at the I.Sc. level an aptitude or interview test, designed to bring out the depth of their scientific understanding or their aptitude for research. Such a test can give relative gradings to within 3%, as shown in Part I of this series, and we would admit only the top 20% or so to an honours degree course in science. The rest should go on to a pass degree and then be absorbed as assistants or else undertake technological training for work in industrial units

TABLE 1.—TABULATION OF OVERALL GRADES OF THOSE JUNIOR OFFICERS GETTING (II+II) OR (I+III) UP TO I.Sc. LEVEL.

No.	Matric	I.Sc.	B.Sc.	M.Sc	Overall grade index
1	II	II	II	II	4
2	II	II	II	II	4
3	II	II	II	III	3
4	II	II	III	—	2^+
5	II	II	III	II	3
6	II	II	II	I	5
7	I	III	I	—	4^+
8	II	II	III	I	4
9	II	II	III	II	3
10	II	II	II	II	4
11	II	II	II	II	4
12	II	II	III	III	2
13	II	II	II	II	4
14	II	II	II	III	3
15	II	II	II	I	5
16	II	II	II	III	3
17	I	III	II	II	4
18	I	III	II	II	4
19	II	II	III	—	2^+
20	II	II	II	II	4
21	II	II	II	—	3^+
22	II	II	III	I	4
23	II	II	II	II	4
24	I	III	III	I	4
25	II	II	II	II	4
26	II	II	I	II	5
27	II	II	II	II	4
28	I	III	II	II	4
29	II	II	II	II	4
30	II	II	II	II	4
31	II	II	II	—	3^+
32	I	III	III	—	2^+
33	II	II	II	I	5
34	I	III	II	II	4
35	I	III	II	II	4

Note.—Those persons who did not take on M.Sc. degree have a plus mark after the grade index calculated from the first three examinations, because the M.Sc. division could either be a II or a III. For the histograms, half the 3^+ would count as 3 and half as 4.

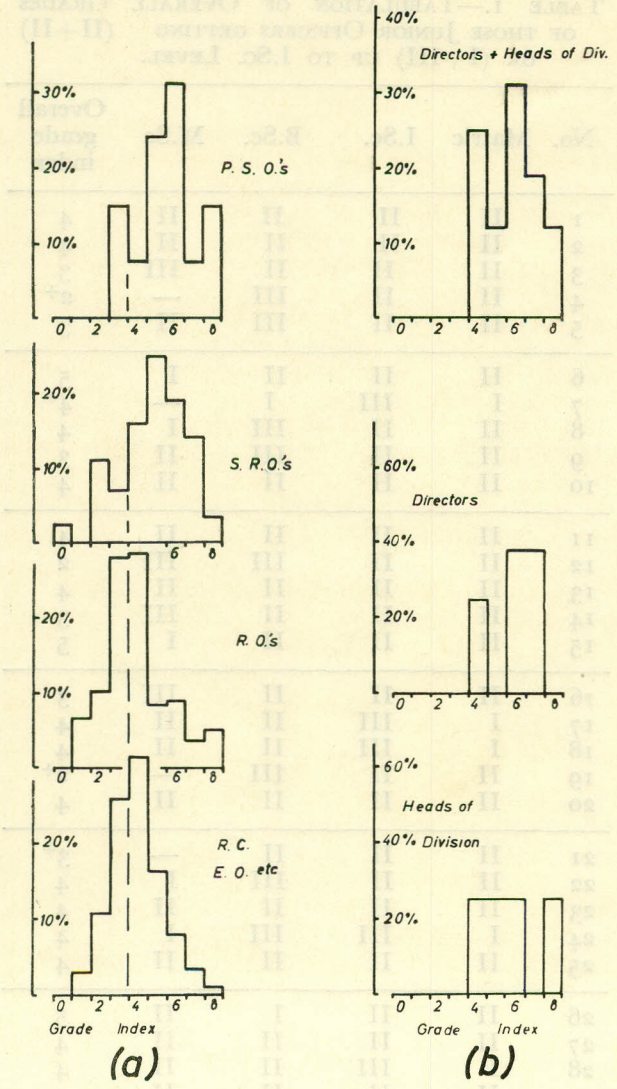

Fig. 1.—(a) Mean histograms for the frequencies of various academic grades for four categories of scientific officers (up to P.S.O.) in the Defence Science Organization and the Central Laboratories of the P.C.S.I.R. The grade index is worked out by allowing one unit for each II division and two units for each I division. (b) Corresponding histograms for the two next higher categories of Heads of Division and Directors, with their combined histogram at the top.

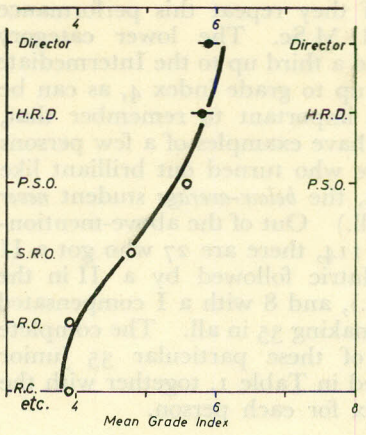

Fig. 2.

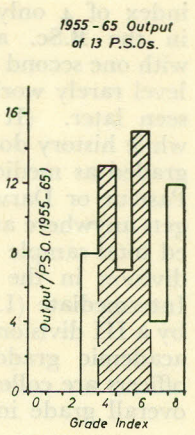

Fig. 3.

Fig. 2.—Synoptic graph showing the variation of the Mean Grade Index (for each category) with the category of Scientific Officers. The upper and lower limiting values are seen to be 3.8, and 6.3, approximately.

Fig. 3.—Histograms of grade index versus research output per P.S.O. during the previous ten-year period from 1955-65, showing that the highest output comes from those with grade index 4 to 6.

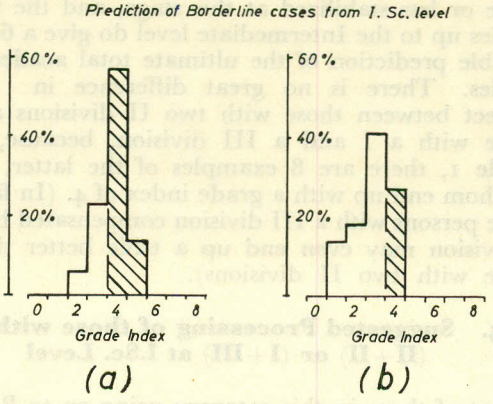

Fig. 4.—Histograms of the *ultimate* academic grade index attained by those who were borderline cases at the Intermediate examination level, namely those (a) with II+II or I+III up to the Intermediate level, and (b) with II+III or III+II up to this level.

or laboratories. A very useful alternative to such an interview or aptitude test is to obtain "integrated reports" from the student's class-teachers indicating his potential as a scientist, based on their observations of his class and laboratory work, and his method of tackling problems, as distinct from his academic showing.

The students passing out of I.Sc. with a (II+III) or (III+II) should preferably be trained as technicians, where the elementary scientific knowledge will be useful. In no circumstances should they be allowed to go on to an honours degree course, because they will rarely go beyond grade index 3, even after passing M.Sc. (as shown by the histogram of Fig. 4(b) for a subsample of 22 from the previous total sample of 114 which is already biased towards scientific aptitude), and it will then be too late to make even good technicians out of them. It will be realized that the purpose of such career planning is to guide and occasionally coerce students into the most suitable lines of

training and work, and we should therefore leave a small portion of seats (say 10%) in universities untouched by such planning, so as to allow for some of the more independent and late-flowering, but otherwise capable, people. In any case, one cannot make this planning completely rigid, because a good research scientist is compounded of a large number of qualities, all of which cannot be determined by academic showing alone, as for example in case of the highly productive scientist with grade index of 4 in the histogram of Fig. 3. Also, planning must be coupled with a fairer distribution of salaries between the technicians, the assistants, and the white-collar scientist and engineer categories. This may perhaps require the institution and expansion of an Experimental Assistant and Experimental Officer class, in which the topmost salaries would ultimately be as high as those of Principal Scientific Officers or Readers at the unversities.

6. Lines for Further Study

Although reasonably complete in itself, the foregoing analysis must be regarded as a first step towards the evolution of a proper system of scientific education and career planning for our young men. The details of a system of testing and screening after the I.Sc. would itself require considerable further work, and doubtless some senior educationists may like to attack this problem. An interesting facet would be a study of the factors that make the scientists with grade index 4 to 6 so productive. Further analysis with a set of larger samples is desirable. Several other lines of study could emerge from this, such as, for example, the possibility of a back-and-forth flow between teaching institutions and industry so as to provide some of the abler technicians with courses of basic or advanced scientific knowledge. Another aspect of some importance is the rate of turn-over, i.e. shifting of scientific workers from one category of work to another. Too low and too high a turn-over rate is obviously unhealthy, and so a study of its optimum value for this country would be of use in the optimum utilization of our scientific talent. Another important facet not touched upon here pertains to the situation in university teaching departments, where teaching and research are combined in each department, and it is hoped to examine this separately for possible correlations with academic grades, etc.

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Reference

1. M.M. Qurashi, Pakistan J. Sci. Ind. Res., **11**, 330(1968).