THE EFFECT OF INDUSTRIAL VALUES ON SCIENCE: AN EXPLORATORY STUDY

by

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ABSTRACT

A study was made of the attitudes of pure and applied science, economics and commerce students toward the acceptability of commercial goals for scientific research. A significant amount of discrimination was obtained amongst such groups of students on a battery of attitude statements and a scale was constructed from sixteen of the statements which gave the highest discrimination between commerce students and a combined group of pure and applied science students. The discrimination between the two groups on this scale was at the .001 level. The commerce students were significantly less homogeneous as a group and gave responses which were less internally consistent than those of the science students.

In the second phase of the research, scientific originality was rated on the results of a test called "Problems and Solutions" which called for the production of ideas in an industrial and a non-industrial context. The within- and between-rater reliabilities of this test were .88 and .58 when degrees of originality were assessed, whereas the latter was .85 when only the presence or absence of originality was assessed.

The results of the second study showed that scientific originality was significantly less in the industrial context,

and that the ideas produced in that context were significantly more often of a commercial nature. In the sample as a whole these two effects of the problem context were unrelated. Detailed examination of the results revealed the probable existence of three types of subject, designated the 'uncreative pure scientist', the 'creative applied scientist' and the 'creative pure scientist'. The first was characterized by zero scores for originality in both context, by the production of more commercial ideas in the industrial contexts, and by a more pure-science orientation as measured by the attitude scale. The second type was characterized by the production of more commercial ideas and a higher originality score in the industrial context. The third type was characterized by a lower originality score in the industrial context and the production of fewer scientific ideas in that context, rather than (at least in comparison to the other two types of subject) the production of more commercial ideas.

The results did not support the hypothesis i) that the adverse effect of an environmental value system is positively related to the degree of dissonance between its values and those of an individual in that environment; ii) that the reduced originality of scientists in an industrial test context is a result of their conforming to an image of industrial research ideas having to be both commercial and conventional in order to be acceptable; iii) that the more creative the individual, the greater the adverse effect of a possible constraint perceived in the industrial value system, as considered here. There was limited support for the hypothesis that the least creative individuals are most likely to produce ideas of a commercial type in an industrial context.

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1. Introduction and literature survey

The primary purpose of this research was to test the validity of the belief, quite widespread amongst scientists and others, that the economic, commercial and pragmatic values sometimes stressed in sectors of industry may have an adverse effect upon scientists' originality. A secondary purpose, assuming that any such adverse effect could be demonstrated, was to examine its relationship to scientists' attitudes toward industrial values regarding scientific research, to their level of scientific originality and to their tendency to conform in their scientific thinking to the normative pattern implicit in an economically oriented industrial value system. Kornhauser[11] and Lerner[12] are among those who warn of the possibility of such an effect.

Previous research appears not to have included any direct experimental tests of this belief, but to have provided only inferential clues derived from the study of scientists in industrial, government and other research settings. Principally, these studies have looked at the relation between freedom, satisfaction and productivity of research scientists.

For example, Meltzer and Salter[15] found that physiologists working in government and independent research laboratories had a higher output of research papers and greater satisfaction with their working conditions the more freedom they considered they possessed. If this research finding is to be related to the hypothesis basic to the present study, one must apparently assume that the number of research papers published can be accepted as a measure of the degree of originality, and that freedom, or the converse, is a constituent dimension of the value system of industry in relation to scientific research.

In an earlier study Meltzer[14] showed that the number of papers published during a period of three years correlated to the extent of r = .51 with the number of citations for their authors in the Annual Review of Physiology. But it was not shown that the latter criterion was correlated with direct assessments of scientific originality. Liebermann and Meltzer[16] had previously found that the output of publications correlated positively with orientation toward pure science in physiologists. Hilberg and Honey[2] found that freedom to follow their own research interests was a frequently mentioned reason for government scientists changing their jobs: it might be inferred that this reflected a feeling on their part that lack of freedom was inimical to their own creativity, but once again a direct link with the present is lacking.

Smith[18] found from interviews with research scientists that, among other items, uncertainties about the research budget, lack of long-range research planning, insecurity over the possible discontinuation of their research, and relative lack of personal autonomy were factors which the scientists regarded as deleterious to their work. It will be seen subsequently that these factors can be regarded as components of the industrial value system regarding scientific research, at least in its more extreme form.

A study by Pelz[17] showed that scientific performance, as assessed by researchers' colleagues, was significantly associated with an orientation toward pure science, but only where identification with the institution and its goals was low. This suggests that the scientist who has a preference for pure, basic research, but who is sufficiently conformist to identify with the more pragmatic, economic values of the organization, functions at a lower level of originality than the scientist who maintains an independence of the organization.

The problem of reliable measurement in the study of originality is shown in a paper by Taylor[20]. A Thurstone-type rating scale was constructed of statements about attitudes and habits relative to creativity and scientific productivity; the scores obtained for research physicists and engineers correlated only to the moderate extent of $r = .67$

with estimates of the subjects' creativity made by their research supervisors. Thus over half (55 per cent) of the variance of subjective estimates of scientific creativity is not attributable to reliable assessments of specific traits such as attitudes and work-habits. Whether, in that case, overall subjective evaluations by research colleagues and superiors can be accepted as an ultimate criterion against which precise measures of originality should be validated is questionable. In a study by Jones[10], ratings of scientists by supervisors were obtained and the results of a number of tests were correlated with these ratings to obtain, by multiple regression, an optimum set of predictors of creativity. Combining six weighted scores gave a correlation of .67 with the supervisors' ratings. The six items were reasoning ability with symbols, ideational fluency, original ideas, emotional stability, dominance toward the work milieu, adventurousness of outlook, scientific curiosity and low general anxiety.

As regards attitudes toward pure science among scientists, only one study by Hinrichs[9] appears to have involved statistical methods of analysis, as in the present research: the remainder were based on impressionistic descriptions of scientists' attitudes. Briefly, Hinrichs found by means of factor analysis and discriminant function analysis that attitudes valuing freedom and pure science discriminated at a low but significant level between chemistry Ph.D. graduates (1961) choosing academic employment in preference to industry. Remarkably, however, this same attitude cluster accounted for only 7.8 per cent of the total variance of scientists' attitudes toward science, industry and autonomy. Two other factors accounted for 5.6 per cent and 4.3 per cent, namely materialistic attitudes accepting business values, even at the expense of science values, and an applied science orientation, according to which little conflict was seen between industrial and scientific values. It is not clear why 82.3 per cent of the total variance remained unaccounted for in Hinrich's factor analysis.

To summarize, it appears that no experimental studies of scientific originality in an industrial context have been reported in the literature, and that the studies of scientists working in industry provide little more than inferential evidence concerning the possible effects of industrial values upon scientific thinking , and that no comprehensive theory has yet been developed in this area, within which the present study might be placed.

For an exploratory study, designed to explore the factual basis for beliefs in the effects produced on scientific originality by a certain type of environment, it was considered premature to attempt to develop an extensive theoretical framework, partly because three distinct theory systems could be envisaged, each characterized by a distinctive central postulate, which it was scarcely possible to integrate into a single theory and scarcely worth adumbrating separately and at length until it was known whether there was any factual basis for theorizing in this area. To anticipate the subsequent detailed discussion of results, this view was justified by the fact that none of the three hypotheses central to these theories survived the first empirical test, once the relevant data were available.

2. Attitudes toward industrial science

One purpose of the present research was to see whether scientists having different attitudes toward the 'commercialization' of industrial scientific research would be differently affected, as regards their level of scientific originality, by an industrial context. For this purpose it was desirable to measure such attitudes on a scale, and since no scale sufficiently closely related to the problem under investigation was known to me, it was necessary to construct one.

The first step in the construction of a suitable scale was to analyze the concept of an industrial value system pertaining to research into its constituent elements, and this produced the following eight-fold scheme:

I. Economic value. A tendency to solicit and support research the anticipated results of which would be of financial or utilitarian value to the agency providing financial support for the research and exercising a right of decision over it.

II. Planning. Pressure to decide well in advance the methods and apparatus to be used in the research, in order to assess the budgetary investment required for equipment, personnel and services.

III. Concreteness. A. The tendency for projects having predicted results readily understood by practical, non-scientifically trained sponsors to be preferentially approved.

B. Pressure to discover new facts and techniques, rather than seek new theoretical developments.

IV. Prediction. Expectations laid upon research scientists that they predict the specific results, or type of results, likely to be obtained from their research.

V. Convergency. A. Specification of research goals prior to the project planning stage, rather than acceptance of unplanned results from relatively undirected research.

B. Pressure toward the application of well-established scientific concepts, in preference to the 'risk' involved in new and untried theories.

VI. Urgency. A. The tendency to sponsor research that can be completed quickly.

B. The tendency in certain economic circumstances to reduce the time-span allocated to a research project and attempt to accelerate the rate of progress.

VII. Conditionality. The tendency to withhold approval for a complete research project, making approval of each successive stage dependent upon the sponsors' evaluation of earlier stages in relation to prevailing circumstances.

VIII. Routinization. The tendency toward a reductionist belief that science requires 'nothing more' than the application of a specific method by any person who has completed the relevant formal training.

Thirty statements embodying these conceptual factors were then constructed, in fifteen pairs, one member of each pair being so worded as to imply approval of industrial values, the other approval of a pure-science orientation toward approximately the same topic. The thirty statements were incorporated in a questionnaire on which subjects could indicate their opinion about each statement on a five point scale, from - 2 (X X) for strongly disagree, to + 2 (✓✓) for strongly agree. The order of the statements was randomized, <u>except</u> that i) at least four statements separated each statement from the one worded oppositely to it; ii) statements occurred in runs of not more than three of the same sign (for or against 'pure science'), and iii) the statement placed first was intended to be such that practically all subjects would reject it, since it was desired to overcome an anticipated tendency for subjects to agree, irrespective of their real opinion. The instructions accompanying the schedule sent out to subjects also emphasized the possibility of their disagreeing, as well as attempting to polarize their opinions by mentioning typical views for and against a belief in the compatibility of science and industry, and by suggesting that all the subjects were "no doubt aware of some of the factors involved...". The statements in the order in which they were presented in the questionnaire were as shown in Appendix I. The category of the industrial value system to which each is intended to refer is shown in parentheses.

Cyclostyled copies of the attitude schedule were mailed to 200 senior students at the University of British Columbia, their names and addresses having been extracted from records of the university registrar. All the subjects were male fourth year students majoring in either a pure science subject (physics or chemistry only); or an applied science subject (metallurgical engineering, chemical engineering, mechanical engineering or engineering physics); or economics; or commerce and business administration. Each subject was chosen on the basis of his record being in the appropriate section of the file for that subject group, and of its showing a preponderance of fourth year courses being taken in his special field of study. No attempt was made to sample the file strictly according to a randomized procedure, since this would have interfered unduly with the work of the registrar's office. Instead, letters of the alphabet were chosen at random and all the students whose names occurred in those sections of the file and who met the selection criteria (including the availability of an apparently complete and correct Vancouver address) were noted, to a total of fifty for each subject group, and equal numbers for each academic subject within a group, as nearly as possible.

The schedules were despatched and a follow-up sent out with a duplicate copy of the schedule to those who had not replied after two weeks. The number of questionnaires returned was 113 out of 200 (56.5 per cent), of which 110 were correctly completed and returned before the data analysis was well under way.

The method of analysis adopted had to meet two requirements: it had to enable the existence of differences between the attitudes of scientists and non-scientists in the sample to be tested; and it had to make possible the construction of an interval scale for the representation of attitudes toward industrial science.

An examination of several procedures which have been used for scaling led to the conclusion that the two requirements mentioned above could probably be met by the method of Multiple Discriminant Analysis (Cooley and Lohnes[15]). This is a technique which produces one or more weighted combinations ("discriminant functions") of scores on a number of items, such as attitude statements in the present case, each of which functions corresponds to a maximum degree of discrimination, or separation, among the groups of subjects whose responses are used in the analysis. The computation of weights for each of a battery of items is equivalent to plotting the individual responses in as many dimensions as there are items (thirty in the present case), and finding an axis along which the groups have the greatest overall separation. A second axis, perpendicular to the first, is then found, along which the groups are next most widely separated, and finally a third such axis is found. In the present case, with four groups, there are three such axes, each corresponding to a distinct discriminant function and a separate set of weights for the constituent items.

For these axes it is then possible to compute, first, a measure of the degree of discrimination existing among the groups of subjects and, second, a single score for each subject, on each discriminant function, made up of the appropriately weighted sum of his responses to the constituent items. The former would reveal whether there were in fact significant differences among the four groups, and the latter would place each subject on three orthogonal scales, each defined by the typical patterns of attitudes of the groups of subjects situated at different positions on the scales. To be specific, it was hypothesized that scientists would be found grouped at one end of the principal scale extracted by this method, with economics and business students at the other end. If this were found to be the case, it could be said that the scale represented a Science-Commerce dichotomy as regards values concerning industrial research. This would be relevant to the question which this part of the study was designed to answer. Thus, the specific hypotheses which it was intended to investigate were as follows.

1. That there would be a significant amount of discrimination revealed by the analysis;

2. That this would be concentrated in one of the three discriminant functions which were theoretically possible results of the analysis;

3. That on this principal function, the pure and applied science groups, and the economics and commerce groups, would be at opposite ends of the scale, and probably in the order indicated, though it was uncertain whether economics or commerce should be expected to be at the other extreme from pure science;

4. That the typical patterns of response to the attitude statements, by subjects in the different groups, would correspond to the concepts which had been built into the schedule, i.e. clusters of attitudes in favour of pure science and in favour of economically oriented applied science.

Results*

The complete computer programme (taken with slight modification from Cooley and Lohnes[15]) for multiple discriminant analysis produced first the means and standard deviations for each of the four sample groups on each of the thirty statements.

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* The results reported here could scarcely have been obtained without the invaluable help in compiling and running the computer programmes, given by Dr. Hugh Dempster and other members of the U.B.C. Computer Centre; and without the availability of a tested programme for Multiple Discriminant Analysis in Cooley and Lohnes' text on mathematical methods [15].

For this purpose, the five response categories from strongly disagree to strongly agree were represented by the scores 1 through 5.

The computer programme then produced the 30 X 30 matrix of correlations between all pairs of items. This is not reproduced here, since the matrix as a whole is not particularly relevant to the discussion of results. It is worth noting, however, that the number of significant correlations in the matrix was far above chance level. For example, 70 were greater in absolute magnitude than $\pm$ 0.246, which at the 5 per cent level would be expected to be exceeded only about 9 times in a 30 X 30 matrix, with no more than random association between items.

The three possible discriminant functions obtainable with four groups of subjects were then computed, together with the percentage of the total discriminating power of this set of statements which was associated with each function. These were 68.1 per cent, 18.1 per cent and 13.1 per cent. The fairly large percentage associated with the first function confirmed the second hypothesis, and indicated that a large proportion of the difference among the groups was in the area of one particular clustering of attitudes. That these attitude patterns corresponded to the concepts built into the attitude schedule was shown by the calculated relative positions of the four sample groups along the axis corresponding to the dominant discriminant function. These positions of the four group means, together with the variances of the four groups, are shown in Table I for each of the three discriminant functions.

TABLE I

Means (and variances in parentheses) of groups on three discriminant functions.

	Group	N	Discriminant Functions 1	2	3
1.	Pure science	29	-3.700(.3716)	1.841(.3511)	1.705(.7652)
2.	Applied science	25	-3.303(.3440)	1.259(.6148)	.697(.7184)
3.	Economics	25	-2.045(.3626)	2.186(.6103)	1.030(.9296)
4.	Commerce	31	-2.033(.8099)	1.221(.5505)	1.641(.7646)

It can be seen that the group means on the first function are clearly in line with the third hypothesis, since pure science students are at one extreme, with applied scientists in an intermediate position, and economics and commerce students at almost identical positions at the other extreme. This was not the case for either of the other discriminant functions, and no attempt was made to interpret their possible significance or meaning, since the principal function extracted was the sole object of interest in this study.

Testing the separations within the various pairs of groups by means of the studentized range statistic, q_r (Winer[21]), showed that the pure and applied science groups did not differ at the 5 per cent level ($q = 2.39$; $q_{.05} = 2.80$; d.f. = 2,106), nor did the economics and commerce groups ($q = .59$). The discriminations within all other pairs of groups were associated with probabilities less than .01.

In view of these results, it was not surprising that the overall discrimination achieved by the attitude schedule was shown to be only very moderate, since the two pairs of groups were separately at almost identical positions, so that all the discrimination was between one pair and the other, the discrimination within each pair being almost zero. The amount of discrimination involved in all three discriminant functions acting together was indicated by a variance ratio of $F = 1.36$, with 90 and 231 as the calculated degrees of freedom. Using a one-tailed test in the present case, since the group means were in the predicted order, this variance ratio is just significant at the .05 level. However, the F-value associated with the first discriminant function would be 1.36 X 68.1 per cent = .926, the probability of which is greater than .05.

The only really unexpected finding from this part of the study was the great difference in variance between the commerce group and the three remaining groups. Calculating a pooled estimate of variance from the first three groups in Table I gave a value of .375, associated with 76 degrees of freedom, giving an F-ratio between the commerce and the three remaining groups of 2.16, with 30 and 75 degrees of freedom. Using a two-tailed test, since there was no reason *a priori* to expect one variance to be greater than the remaining three, and allowing for the selection of the largest of four variances, gave a probability of between .04 and .08 of obtaining such a value or a greater one by chance. It may be concluded that there probably was a difference between commerce senior students and students in the other three groups as regards the variability of their attitudes toward industrial science.

The relative heterogeneity of attitudes displayed by commerce students, compared to pure and applied science students, may be interpreted as a correlate of a lower degree of professionalization of those who go into commerce and industry as managers and executives, compared to scientists and engineers. It has been suggested in a study by the Opinion Research Corporation[16] that one element in the potential conflict between scientists and industry is the fact that scientists are unable to regard businessmen as fellow professionals, with what that can imply in the way of relatively cordial working relationships.

After discovering the above-mentioned difference between science and commerce students, it was hypothesized that the greater heterogeneity of the latter would be reflected in a greater inconsistency within the attitudes of individuals toward industrial science, since members of the group, in contrast to those in the science group, would have available to them a less clear image of normative beliefs and attitudes considered appropriate for potential members, than the more professionalized group of scientists. Taking the science (combined) group and the commerce group together and omitting the economics group*, the 20 per cent most 'inconsistent' subjects were identified according to the following criterion. Each of the fifteen pairs of approximately opposite statements was examined for each subject, and his 'inconsistency' score was the number of pairs in which he gave a response of the same sign to both statements. Subjects with a score of nine or more constituted the most 'inconsistent' 20 per cent. It was then found that inconsistent individuals as thus defined made up 12.95 per cent of the combined science group and 32.26 per cent of the commerce group. Using a one-tailed test, since the difference is in the hypothesized direction, t for the difference of percentages has a probability less than .025. Commerce students are thus, on the basis of this study, more heterogeneous as a group and more 'inconsistent' individually, than are pure and applied science students, in their attitudes toward industrial scientific research.

*Only two criterion groups were required to define the extremes of the attitude scale. Since the variances of the economics and commerce groups differed significantly it was not legitimate to combine them, so the commerce group was retained as being the more likely ultimately to be responsible for determining and executing research policies in industry.

For the next stage in the construction of the attitude scale, the starting point was the demonstration, as described above, that there was a highly significant difference ($P < .01$) between commerce students and the combined group of pure and applied science students, as regards their overall attitudes toward industrial scientific research; also the demonstration that it was justified to combine the two science groups, but not to combine the economics with the commerce group, because of their markedly different variances; finally, the demonstration that the discriminant function which separated the groups in the order hypothesized also accounted for a dominant proportion of the total discrimination amongst the four groups, and could thus be used as the basis for a scale which might be expected to have a realistic conceptual interpretation.

The two groups, commerce and pure and applied science, were then taken as criteria for, in effect, defining the two ends of the scale which was to be constructed. The discriminant analysis was therefore re-run, in order to compute the single set of weights theoretically possible with only two groups*. The weights for the thirty items are shown in Table II (Page 20).

The centroids of the four original groups on the principal discriminant function were not always consistent with

* The possible number of discriminant functions is one less than the number of groups or the number of items, whichever is the smaller.

TABLE II

Discriminant weights based on two groups:
Commerce; Pure and Applied Science.

Item	Weight	Item	Weight
1	-.1626	16	-.0508
2	.0012	17	-.0672
3	.1222	18	.0849
4	-.1368	19	-.2170
5	.0649	20	-.3887
6	-.0762	21	.4074
7	-.0467	22	-.1105
8	-.3325	23	-.0356
9	.1134	24	.0585
10	-.1976	25	.2943
11	.1051	26	.3265
12	.3114	27	-.0906
13	-.0466	28	-.1594
14	.0907	29	-.0226
15	.0101	30	-.1552

what had been expected when the attitude statements were drafted. For example, on Statement 1, the pure and applied science groups showed a higher average level of agreement with the statement than did the economics and commerce groups. Possibly the basis for scientists accepting the reference to "everyday common sense" was the emphasis in undergraduate courses on instilling factual knowledge and technical skills, rather than imaginative development of theory and experimentation, as in research. To the extent that the former are successfully mastered, an undergraduate could believe that science has become for him a matter of "everyday common sense".

The same applied to six other statements, namely those numbered 2, 6, 11, 17, 21, 26 and 30. It was concluded that each one had been interpreted to mean something other than had been intended, or else that many subjects' responses had been over-determined by their reaction to an unintended implication of the question. For example, in Statement 6, one can imagine a loyal science student defending the ability of scientists to get results as quickly as anyone else, which is not what was meant to determine responses to the statement: it was based on the hypothesis that pressure to hurry will tend to impair the creativity of scientists, and thus produce 'bad' science. There would, at the best, be little point in including such an item in a scale concerned with the possible effects of industrial pressures on creative science, in view of subjects' responses to the question as worded.

Similar considerations applied to the other statements for which anomalous results were obtained, and it was decided to eliminate all of these from the scaling procedure.

A further six were eliminated on the grounds that they did not discriminate very highly between the commerce and the pure and applied science groups as shown by their weights in Table II being small.

This left sixteen items to be scaled, and the next step consisted in determining, from a third run on the discriminant analysis computer programme, a final set of weights for these sixteen (as shown in Table III). At this stage, the number of subjects whose data was used in the scaling procedure was reduced by the twenty per cent most inconsistent, as defined previously, so as to ensure that the scale itself would be as internally consistent as possible.

TABLE III

Weights for sixteen items from 2-group discriminant analysis

Item No. (in original list)	Exact Weights	Weights X 10, Rounded
3	-.1885	- 2
4	-.1959	- 2
5	-.1403	- 1
8	.2311	+ 2
9	-.0170*	-
10	.3450	+ 3
12	-.4850	- 5
14	-.0925*	-
16	.1802	+ 2
18	.0490*	-
19	.0671*	-
20	.3785	+ 4
24	-.0301*	-
25	-.5202	- 5
27	.1519	+ 2
28	.1129*	-

The six items with the smallest weights, omitted from the 10-item scale, are marked with an asterisk. The rounded weights used for the remaining items in the 10-item scale are shown in the final column.

The tendency for the weights of some items to reverse their sign from one stage of the analysis to the next as the number of criterion groups was decreased is disconcerting. The reason for it is probably that with four groups, the discriminating power of a given item may happen to involve mainly a particular pair of groups, whose means on that item are in a certain order with respect to their order on the discriminant function as a whole: but with a reduction to only two criterion groups, there is no place for irregularities of this type. Thus, providing the two criterion groups are well chosen and appropriate to the specific attitude scale being developed, the weights based on two groups are more meaningful than those based on a larger number of groups.

The F-ratio indicating the degree of discrimination achieved by the selected 16 items between the science and commerce groups was 3.71 (d.f. = 16, 51; $P < .001$).

Validation of the scale defined by these sixteen items and their weights* would need to be carried out on new samples of subjects similar to those used here, but this has not been done as part of the present research.

Of the final 16 items 12 had weights greater than .09 (disregarding the sign). Of these 12, four items (5, 8, 16, 25, the last of which had the highest weight (-).5202 of the sixteen items), represented the Economic Value category of the industrial value system and the other categories were represented by one item each, except VII(two items) and VA, VB and VIB (unrepresented). But VA and B were represented

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* Referred to in this report as the ATIS scale ("Attitudes toward industrial science").

by only one item each in the original list of 30, so their absence from the final list may not show that convergency is not a source of conflict between scientists and industrial management. The same applied to VIB.

3. Scientific originality in industrial and non-industrial contexts.

Before the research design described later in this section was implemented, an unsuccessful attempt was made to carry out a more complicated group-experiment design. It is described here so that it may be evaluated and possibly used by others who wish to study scientific originality experimentally. It included two other major factors in addition to those referred to in the present report, namely the influence of group participation and of the type of leader (scientifically or commercially oriented) appointed in the group. The analysis of variance design called for twenty 4-man groups in a 2 X 2 model, giving five elements (groups, in this case) in each cell of the design. This was regarded as the smallest number that was likely to reveal the possible treatment effects, which were not expected to be dramatically large, even with covariance adjustments for two additional variables, the level of creativity and the ATIS score.

Rather than run the twenty groups separately, which would have been time-consuming, the experimental procedure was designed so that with the help of one or two assistants, all the groups could be run simultaneously. Basically, this was done by conveying most of the necessary instructions to the groups in printed booklets, and by gathering all the necessary data from the groups in writing*. One advantage of such a procedure apart from the time factor, was that it would enable groups and leaders to be allocated to cells of the design on a matching basis, which would involve an extensive pre-experimental test phase if the groups were to be run separately. A further advantage was that the possibility of leakage of information about the creativity tests used in the design was minimized. Since it appeared later that there exists a high degree of solidarity and communication amongst scientists subjected to 'stimulation' (e.g. investigation) from outside their group, this point may be of considerable importance.

However, the elaborate design, and the quantity of booklets, forms and other materials prepared in readiness for it, were never used on more than a single group of four subjects, despite four or five attempts to gather together enough volunteers to make it worth running the experiment. The criterion adopted for this purpose was that about half of the required number of subjects (80), should be available at one time, with a reasonable probability that the remainder would be available on a second or third occasion.

Briefly, the results of the successive attempts and the circumstances in which they had to be made because of other commitments of the writer, were as follows:

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* Copies of the printed materials are shown in Appendix II.

At the end of examinations week at the University of British Columbia, an experiment was run in the Ponderosa Cafeteria, which was ideal for the purpose, after notices had been placed in all the relevant buildings on campus. Five subjects appeared, of whom four could be used for a single group, which was run in order to test the procedure. On the next occasion, one subject appeared, and that session and the session planned for the same afternoon were cancelled.

At Western Washington State College, after the same sort of advertising campaign, five persons appeared on the first occasion, but no group was run. A date was set for the following week, and volunteers who had appeared on the first occasion were asked to get their friends to sign as volunteers on lists which had been posted around the campus. Science faculty members were also requested to bring the matter to the attention of their students in class. By the next week, only a handful of names had been added to the lists, and the writer decided it was not worth the labour of re-arranging 22 tables and 80 chairs and laying out 80 sets of experimental materials; he went to the meeting-place prepared to tell a half-dozen people that the experiment had been cancelled -- and found 28 students waiting, 20 of whom had been sent over as a class unexpectedly by one of the faculty members to take part. Since it required 45 minutes to prepare for the experiments, there was no alternative but to cancel; in any case, even 28 was far short of half the required number.

A final attempt was made, with the help of the chairman of one of the science departments, and 31 volunteers gathered, thirteen of whom had been at the previous meeting. Thirty-one, incidentally, was one short of the number required to give even 2 groups per cell of the 2 X 2 design and despite a search of the building, one extra volunteer could not be found -- until after the 31 had already been dismissed and the experiment again, and finally, cancelled.

Thus, out of 187 third and fourth year science majors at Western Washington State College, about 46 subjects (24.6 per cent) were obtained in three attempts. The pre-established criterion for the feasibility of carrying out the experiments was not met, but in hindsight it can be seen that just enough subjects were obtained for it to have been worthwhile to 'collapse' the experiments to a single-factor design by omitting leadership-style as a variable, and studying only the effect of an industrial context. That possibility was not thought of at the time, and in any case whatever results might thus have been obtained would have been specific to groups under the administrative leadership of a particular type of individual, either science or commerce oriented, depending upon which had been selected. The alternative to selecting a single type of leader for each group, in the single-factor case, would have been to select the leader at random. This, however, would be expected to have increased the error variance, and hence to have diminished the chance of obtaining significant results. On the whole, it seems to have been justified either to carry out the experiment as originally planned, or not to carry it out at all. Having decided that five groups per cell was a reasonable minimum, and having made several thorough but unsuccessful attempts to obtain enough volunteer subjects, there seems to have been no practical alternative to discontinuing that line of research, at least for the time being.

In a sense, the new research design constructed in place of the group experiments was a more logical first step in the experimental study of scientific originality, since it was a study of individuals, not of groups. It was a conceptually much simpler design, consisting essentially of a test of scientific original thinking in two contexts, one economic, the other 'pure science'.

Even this less complex design came near to failing, due to the low rate of return from the science graduate students at UBC to whom the materials were sent. With a 15.5 per cent response rate, only the fact that the materials were sent to all 304 graduates in physics, chemistry and the biological sciences ensured that enough data would be obtained to provide answers to the principal questions being investigated.

Study design

The final research design was extremely simple. Apart from a 10-item, easily scored form of the ATIS test, described in Section 2, it consisted of a test of scientific originality, called the Problems and Solutions test, presented in two distinct contexts, one industrial, the other non-industrial. The wording of the two forms of the test, in the case where the industrial problem related to food products and the non-industrial to clothing, was as follows.

PROBLEMS AND SOLUTIONS. TEST A

Imagine you are an independent research consultant. An industrial corporation seeks your advice on establishing a programme of research to develop new kinds of FOOD PRODUCTS likely to result in a quick and profitable return on their financial investment when marketed throughout the world. A large sum of money is available from the company's sales profits to cover the costs of an intensive one-year research project, which may be extended if the first results are commercially worthwhile.

What problems would you suggest should be studied, and how might they be solved? Write the five most original ideas you can think of on five of the enclosed cards, marking each card with an "A".

PROBLEMS AND SOLUTIONS. TEST B

Imagine you are an independent research consultant. A non-profit foundation seeks your advice on establishing a programme of research to develop new kinds of CLOTHING MATERIALS to meet expanding world requirements over the next twenty years. A large sum of money is available from funds provided by various international organizations to cover the costs of a research project lasting several years if necessary.

What problems would you suggest should be studied, and how might they be solved? Write the five most original ideas you can think of on five of the enclosed IBM cards, marking each card with a "B".

The specifications of the two contexts in which the Problems and Solutions test was presented were constructed so as to correspond, but concisely so, with the conceptual scheme underlying the ATIS scale; that is, with the suggested structure of the value system of industry as regards scientific research.

Referring to the categories defined on Pages 7 - 8, this correspondence can be made explicit by quoting the relevant parts of the specifications for the two contexts.

First, the two contexts were initially broadly defined by the reference to an "industrial corporation" and a "non-profit foundation". Next, Categories I, <u>Economic Value</u> and VI, <u>Urgency</u> were introduced by the alternatives of "a quick and profitable return on their financial investment", and the non-commercial, long-term references "Expanding world requirements over the next 20 years" and "a research project lasting several years if necessary". Category VI, Urgency was introduced again with the reference to "an intensive one-year research project" in the industrial context; and Category VII, Conditionality and I, Economic Value introduced with a reference to extending the research "if the first results are commercially worthwhile".

Thus the context specifications were based on Categories I, VI and VII of the industrial value system schema, this having been largely determined by the need for conciseness and relative simplicity in the test instructions. Both contexts implied a considerable degree of concreteness in the ideas asked for and it would be expected that there would be no differential effect as regards that value category.

The two topics, food and clothing, were selected because of their everyday familiarity, in order to minimize possible advantage to graduates in one specialty over those in another. To anticipate a result reported later, although one might expect biologists to have had an advantage with topics such as food and clothing materials, it was actually found that biological scientists had zero scores for originality more frequently than natural scientists.

For half of the subjects the industrial context was presented first; for the other half the non-industrial context. In all cases the food problem was first and the clothing problem second.

The ATIS test and the two tests of scientific originality were sent, with 10 pre-punched IBM data cards, to each of the 304 candidates for M.Sc. and Ph.D. degrees in physics, chemistry, biology, zoology and fisheries at UBC, whose departments reported them to be still students of the University at the beginning of the summer vacation. The 10 IBM cards were for the subjects to write five ideas on in response to each of the two tests; each idea was to be written on the back of a card, the object being for judges to Q-sort the cards on the basis of their assessed originality, whereupon the assessment would be punched onto each card and the complete set of cards used for computer analysis.

Generalizability of the results

The basic question under this heading is whether results obtained by means of a written test applied to graduate science students could be relevant to the stated objectives of the present research, the first of which was (to recapitulate) "to test the validity of the belief . . . that the economic, commercial and pragmatic values sometimes stressed in sectors of industry may have an adverse effect on scientists' originality". It is perhaps worth pointing out that it was not intended to discover whether scientists in certain sectors of industry are less original than those in others, though clearly it was the writer's intention that the research should be related to the latter problem through a process of conceptual abstraction.

For the two to be related it would seem to be necessary that the scientific thinking of graduate science students in a university be similar to that of research students in a variety of types of industrial setting; and that the situation in which a subject was placed by being presented with the Problems and Solutions test be similar in essence to that which he would encounter in an analogous industrial setting. A third requirement would be that the quality adjudged as "scientific originality" in this study be comparable to what would be so designated in the world of science.

The question whether these requirements would be met to the extent that results of the present research would be predictive of what would occur in a real industrial setting raises the whole problem of cross-validation in the social sciences. As regards the first and third points, experience as a research chemist in university and industry leads me to believe that the requirements were met, whilst the work on the ATIS scale which underlies the construction of the test contexts supports the view that at least the tests contained a conceptual dimension on which scientists and senior commerce students differed significantly. Whether a test presents a situation which is effectively identical to the real-life situation of which it may be intended to be an analogue can hardly ever, if ever, be determined without studying the real-life situation itself. In the present case, it was not thought to be feasible to study research scientists in industry, because of the absence in the locality of a sufficient range of industrial research.

However, if the three aspects of the process of abstraction referred to above are considered to be adequate in the present study, the results reported here are in fact relevant to the objectives of the research as stated.

The second and hardly less important question of generalizability refers to whether respondents in the study reported in the present section could be regarded as typical of the population of science graduate students. A total of 46 graduates returned some or all of the materials; when 29 had been returned by the end of two weeks, and the need for some reassurance to subjects about the use of the results was realized, an explanatory follow-up note was sent out, and an attempt made by personal contacts to get the idea propagated that it was quite safe for graduates to return the materials. This produced another 17 returns during the next 3 weeks, and it was felt that further attempts at follow-up would be unlikely to alter radically the fact that a low rate of return (15.5 per cent) had been achieved. It would seem, however, that the results obtained may be regarded as representative of the whole population sampled, since the subjects who returned the materials were representative as regards the proportions of M.Sc. and Ph.D. students, and of physics, chemistry and biological science students (the only known population parameters); and those who responded before the follow-up did not differ from later respondents (who presumably needed either a reminder or reassurance), as regards the following important variables: Scientific Originality (S.O.) in the industrial context ($P \doteq .8$) and the non-industrial context ($P = .8$); the difference between the S.O. scores in the two contexts ($P > .9$), (degrees of freedom 39 in each case); the proportion of individuals who had zero S.O. scores in both contexts ($P = .6$), (8/24, i.e. .333, and 5/17, i.e. .294 respectively for the industrial and non-industrial contexts); and the score for Attitudes Toward Industrial Science (ATIS) ($t = .80$). As regards the proportion of subjects who failed to return any of the prepunched cards, it is uncertain whether or not there was any real difference between the early and late respondents. Applying Fisher's exact test to the following 2 X 2 table (Table IV) showed that the probability of such a difference between the groups was .087. This result is partly consistent with what would be expected from the known anxiety of the graduate students about the use of the research data, though one might have expected that the ATIS questionnaire, with its questions about attitudes toward industrial restrictions on research, etc., would have been the material not returned. In fact, only 2 out of 29 and 2 out of 17 respondents in the two groups did not return the questionnaire,

TABLE IV

Numbers of subjects not submitting ideas: before and after a follow-up note was despatched.

	No IBM cards returned	IBM cards returned
Pre follow-up	5	24
Post follow-up	0	17

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there being no significant difference between these two proportions.

If it is accepted that there was little or no difference between the pre- and post-follow-up groups, and that the academic status of respondents was representative of the population, then it can be argued that the possibly threatening nature of the research did not exclude as respondents a type of individual so different from the actual respondents that the results would not be typical of the whole population. The basis for this conclusion is that the sample of respondents already includes 17 individuals who presumably were unwilling to respond while they felt insecure about the motives of the research, and these 17 apparently did not differ in any significant respect from the 29 who responded before the follow-up. It is therefore suggested that the findings of the research can be accepted as true of the population of graduate students of pure science.

Assessment of originality and style

Originality in the ideas returned by respondents on the backs of the prepunched IBM cards was assessed entirely subjectively by me, and a comparison rating was made by another person for a selected sample of 48 cards. Assessment was made on a four-point scale, the following description of which constitutes an implicit definition of the operational concept of scientific originality as used in the present research.

Category Zero: Ideas which were not relevant to the problem as specified, or were unspecific, or unrealistic, or were completely obvious and trivial.

Category One: Ideas which were relevant, specific and realistic, but lacked a quality ('originality') of unusualness and newness in relation to other ideas submitted.

Category Two: Ideas which were relevant, specific and realistic and showed some noticeable originality.

Category Three: Relevant, specific, realistic ideas which had an immediately striking quality of unusualness and newness about them.

These definitions were established before any of the ideas were examined, and it was not known how well they would serve in practice, nor what proportions of ideas would have to be put into each category. Upon examining the first 200 cards received, it was found that 50 per cent could only be placed in Category Zero, in my opinion, and another 25 per cent in Category One. Very few ideas gave an initial striking impression of originality, and it was decided to set 1/16th and 3/16ths as the proportions for Categories Three and Two respectively. The reason for setting a fixed proportion for each category was in order to eliminate the possible but irrelevant effect of the nature of the problem (food or clothing) which a subject encountered in the two contexts, since it was thought that the ratings might be dependent to some extent on the topic referred to.

Each idea was rated twice by me. The product-moment correlation between the two ratings, expressed as normal deviates was $r = .88$, with $N = 377$.

Since the ideas submitted were found to differ from one another as to whether they referred to such commercial matters as supply and demand, cost and advertising, it was possible to study this variable (designated here as "Style") in relation to originality. First, however, it was necessary to ensure that the ratings of originality were independent of style, in case any bias on the part of the rater intruded into the rating procedure. Apparently this did not occur, since the values of χ^2 were only .589 ($P > .4$) and .004 ($P = .95$) for the food and clothing problems respectively, and .515 ($P > .4$) and .405 ($P > .5$) for the industrial and non-industrial contexts. The style rating, made dichotomously, was subjectively very easy, being based upon the presence or absence of explicit references to advertising, costs and, in general, the state of the market: no measurement of the within- or between-rater reliability was considered to be necessary for the present research purposes, since it was obviously very high.

To test inter-rater reliability of the originality assessments, 48 cards were selected, such that for each card my own two ratings were identical, and such that 24 were in Category Zero, 12 in Category One, 9 in Category Two and 3 in Category Three. A further 12 cards were selected, three from each of the four categories, my ratings being again identical for each card.

After fully describing to him the definitions and rating procedure, the latter twelve cards were shown as examples to the second rater, a doctor of medicine whom I considered to be both research-oriented and sensitive to the problem of scientific originality. He was asked to sort once quite quickly through the 48 cards, dividing them roughly into a half for the lowest category, one quarter for the second category, "very few" for the highest category and the remainder for Category One, then to repeat the sort (the first having served to familiarize him with the general quality of the ideas) more carefully, obtaining approximately the correct numbers (24, 12, 9, 3) in the four categories, and finally to move cards selectively between categories so as to obtain exactly the predetermined distribution. The correlation* between the two raters' assessments was r = .58 (P< .001). This is significantly less (P = .000001) than the within-rater agreement. It was evident by inspection that ideas which one rater had assessed as highly original the other had not considered very highly, and vice versa, and it was found that product-moment r for ideas other than those which both judges had placed in the Zero Category was only .156 (d.f. = 29, P ≑ .4) which is far from significant. Yet when Categories Zero and One were combined, and Categories Two and Three were pooled to form a single category of ideas having some originality, the two raters' assessments agreed to the extent that the probability (by Fisher's exact test) of the observed agreement or better was .00037. Tetrachoric r was .846 (by the cosine approximation), the significance of this value being indicated by the exact probability of .00037 just quoted, since the sampling distribution of tetrachoric r is not known accurately. Thus, it was evidently much easier for the two raters to agree on whether or not an idea had any originality,

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* In order to convert the ordinal originality scores into a form for which product-moment correlation would be appropriate, a principle analogous to that used in biserial correlation was applied. That is, the proportional frequencies of the successive scores were compared with areas under the normal curve, and the normal deviate, Z, corresponding to the mid-point of each area was used as the normalized score for that level of originality to compute product-moment r.

than on whether it had much, little or no originality.

For each idea a pooled score was formed from the two assessments made by myself, using the following system.

First and Second Assessments	Pooled Score
0,0; 0,1; 1,0; 1,1	0
1,2; 2,1; 0,2	1
2,2; 3,1; 1,3	2
2,3; 3,2	3
3,3	4

The sum of the scores thus obtained, for each item submitted by a subject in a given context, was his score for scientific originality. This is referred to here as the "extended" score, in contrast to the "reduced" score, in which extended scores of 2, 3 and 4 were each designated by unity, and scores of 0 and 1 by zero. The reduced score was thus a dichotomous indication of originality or lack of originality. As for the extended score, the reduced scores for a subject were the sums of the reduced scores for the ideas submitted in the two contexts separately.

Since some subjects submitted less than five ideas (none at all in one or two cases) for one of the two contexts, their score was composed of the sum of scores for the ideas they did produce.

To summarize, it can be seen that the measure of originality employed here is both qualitative and quantitative: in the extended score, one "strikingly original" idea would score as much as two ideas with merely noticeable originality, while an idea which was judged once as merely original and once as strikingly original would score as much as $1\frac{1}{2}$ ordinary original ideas. The latter point raises the problem of whether an idea which was rated the same on two occasions by a rater had an inherent quality distinct from one which received different ratings on two occasions. Within-rater and between-rater disagreement is generally assumed to be due to randomly distributed errors of judgment and not to differences in the difficulty of judgment, or some other quality inherent in the material being rated. It should be made explicit that that assumption has, in effect, also been made here, since it would involve a separate and lengthy study to determine the structure of subjective judgments of scientific originality. The assumption is, however, at least open to doubt.

As regards the validity of the Problems and Solutions test, the only attempt to relate this to an external criterion led to negative results, namely that the originality scores of the M.Sc. students tended to be higher than those of the Ph.D. students, though not significantly so ($P \doteq .3$ for chemists, $P \doteq .1$ for physicists by the Mann-Whitney non-parametric test; .5 and .16 by Student's-t for the extended scores; .5 and .5 by Student's-t for the reduced scores; 2-tailed in every case). Whether Ph.D. students should be regarded as being likely to have higher scientific originality is a moot point, and clearly dependent upon the selection criteria, both manifest and latent, applicable in a particular graduate school.

Subjective ratings of the respondents by their faculty supervisors were not sought as a possible validity criterion for two reasons: first, as reported previously in the discussion of Taylor's[20] study, supervisors' ratings do not correlate very impressively ($r = .67$) with scales on which numerous specific traits can be rated with, presumably, greater precision than is possible in an overall impressionistic assessment. Second, the difficulties that had been encountered in obtaining responses from graduate students led me to anticipate that the administrative difficulties involved in getting faculty ratings of graduate students would be out of proportion to their probable utility. The Problems and Solutions test therefore remains unvalidated, other than by the fact that two scientifically trained persons reached a substantial degree of agreement ($r_{tet} = .846$) on the estimation of whether originality was present or absent, and by the main finding of this study, indicating that whatever was measured by the Problems and Solutions test was affected by an industrial context in a way in which scientific originality had been held to be affected.

Results

Before reporting the results, it should be reiterated that the assessments of originality were made 'blind', that is without knowledge of the context in which the ideas had been produced. Since there was no significant association between commercial style and rated originality of individual ideas, it is unlikely that the former served as an unconscious clue indicating to the rater the context.

Most of the reported results have been based on non-parametric tests, but ATIS scores have been treated as an interval scale measure, since this appears to be justified by the method of developing the scale for this study (see Cooley and Lohnes[7]). The fact that the science and economics groups of students had equal variances on the ATIS scale, though their mean scores were 2.7 standard deviations apart, suggests (because it had been argued previously that such similarly professionalized groups should have similar variances) that the scale has the equal-interval property across the relatively wide range. Where the originality scores have been treated as an interval measure, more conservative tests have been used additionally to show that the results were not dependent upon this assumption.

The basic question to be answered in this study was whether scientific originality tends to be less in an industrial than a non-industrial scientific context. By means of a paired comparisons Student's-t test*, it was found that there was an effect in the expected direction associated with a probability between .005 and .01 ($t = 2.58$). Four non-parametric tests led to the same conclusion. The number of subjects whose "reduced" Scientific Originality scores were less in the industrial context was 15, whilst for 6 it was greater and for 20 the same in the two contexts. The binomial probability of 15 out of the 21 who changed at all being less is only .001. The proportions of zero reduced scores, zero extended scores and scores below the median of the pooled scores for both contexts were all greater in the industrial context: the results for the three one-tailed tests for correlated proportions (McNemar; see Ferguson[8a]) were respectively $Z = 1.94$, ($P = .026$), $Z = 2.11$, ($P = .017$) and $Z = 1.73$, ($P = .042$).

The effect of context on originality was not due to fewer ideas being submitted for the industrial problem. Only 9 out of 41 subjects did not submit the same number of ideas in the

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* Providing the extended scale for originality did not depart too widely from being an interval scale, it was appropriate to use such a test, because the originality differences scores were approximately normally distributed, despite the large number of subjects who scored zero in both contexts. Dividing the range of difference scores at the points -4.5, -2.5, $-.5$ and $+1.5$ to give five nearly equal sized categories yielded a value of $\chi^2 = 7.01$ (d.f. $= 4$; $.10 < P < .20$), indicating that the deviation from normality was not significant.

two contexts, and of these, 3 had fewer ideas in the <u>non</u>-industrial context. The binomial probability of this result is .254; hence there was no significant effect of context on the number of ideas.

An interesting subgroup of subjects, on whom further statistical exploration was carried out, were those who scored zero on the extended scale for originality in both contexts. Fifteen scored zero in the non-industrial and 22 in the industrial context (out of 41 who submitted any ideas), but 13 scored zero in both contexts, which is greater ($P = .001$) than the number that would be expected if scores in the two contexts were unrelated. Those who scored two zeroes had higher ATIS scores (i.e. were more "pure science oriented") on average than those who scored above zero in at least one context ($P = .005$; 2-tailed). This was true for both the biological sciences and for physics plus chemistry, as shown in Table V.

The value of t associated with the two right-hand values is only .44, which is far from significant; the two left-hand values are virtually identical. Pooling the results for the two academic groups yields the probability of .005 quoted above.

Those with double-zero scores for originality were also significantly more homogeneous as regards ATIS score ($F = 5.61$; d.f. = 8, 21; $P < .01$).

TABLE V

Mean attitude scores for subjects scoring zero for originality in both contexts; and others.

	Double Zero	Others
Biological Sciences	31.42 N = 7	22.16 N = 6
Physics plus Chemistry*	31.80 N = 5	23.84 N = 19

*There were respectively 3 and 2 double-zero scores amongst physicists and chemists.

A smaller proportion of physics plus chemistry graduates had double-zero scores (compared with biological sciences) as shown by the following distribution (Table VI), but the associated probability was .074 by Fisher's exact test, so it is not certain whether the observed relationship was due to chance.

TABLE VI

Number of double-zero scores among biological and physical scientists.

	Double Zero	Others
Biological Sciences	7	7
Physics plus Chemistry	6	21

Scoring zero in both contexts was unrelated to whether or not a subject returned the research materials before or after the follow-up note was sent out, to whether he was an M.Sc. or Ph.D. candidate, and to whether the industrial context was presented first on the forms sent out to him.

It is to be noted that the results reported above refer to both the extended and reduced scales of originality, and hence that the subjects referred to submitted no ideas that were rated as better than trivial, irrelevant and/or unrealistic. It seems remarkable that there should be such a clear-cut association between a pure science orientation and scientific triviality, etc., but the results appear unequivocable. These subjects constituted a subclass of those whose originality scores did not differ in the two contexts, but the finding that on average the score in the industrial context was less includes those who scored zero twice.

Amongst those who did not get double-zero scores, there was no difference in ATIS score between those whose score was reduced in the industrial context, and those in whom it was increased, nor between those whose score changed considerably in either direction, and those who had similar or identical scores (other than zero) in both ($t < 1$ in each of these tests). The latter test for a curvilinear relationship was made because the only two subjects who had identical scores other than zero in the two contexts had fairly high

ATIS scores of 28 and 29, which were quite close to the mean for those who scored double-zeroes (3.16). But clearly it would be unreliable, only the two subjects being involved, to group them with the latter and thus 'discover' that those whose scores changed greatly in either direction differed as regards ATIS score from all those whose scores were almost or completely unchanged. The higher ATIS score almost certainly was characteristic only of those whose originality score remained unchanged specifically because it was zero in both contexts. Scientific Originality (reduced scores) was not related to ATIS score either linearly or curvilinearly, in the industrial or the non-industrial context, as shown by "between" over "within" variance ratios of less than unity (d.f. = 3,21) and 1.614 (d.f. = 2,22; $.1 < P < .25$) respectively, obtained by grouping S.O. scores 0, 1, 2, 3 - 5, and 0 - 1, 2 - 3, 4 - 5 in the two cases respectively. The detailed results did not show a monotonic trend in either case, There was no association between ATIS score and the extended S.O. difference score ($t = .93$; $P \doteq .3$), when subjects having positive and negative difference scores were compared.

When the effect of context on extended originality scores was analyzed by subject and degree, no differences associated with probabilities lower than about .3 (allowing for selection) were found.

Considering only those subjects who scored above zero in at least one of the two contexts, the differences between their two S.O. scores was found not to be significantly related to their (reduced) score in the industrial context (Fisher's exact test, $P = .126$). And there was no significant tendency ($\chi^2 = .296$; $P \doteq .6$) for the number of ideas having higher originality scores (3 or 4) to be reduced in the industrial context proportionately more than the number of ideas having only a low level of originality (a score of 2 on the scale 0 - 4). Using the Kruskall-Wallis test (Winer[21]) indicated that there was no interaction effect of the level of originality and ATIS score acting simultaneously on the originality difference scores. That is, the rank-ordered originality difference scores showed a (non-significant) relationship to level of originality, and this relationship was not dependent upon ATIS score. Values of the parameter H(distributed as χ^2) were only .63 and .24 at levels of originality below and above the median respectively. Adding these values to give $\chi^2 = .87$ (d.f. = 2 by adding degrees of freedom) gave a probability $.5 < P < .7$ for the hypothesis of no interaction.

The second dependent variable in the experiment was the 'style' of the ideas produced, that is the presence or absence of references to commercial factors such as costs, supply and demand, and advertising. Since not all the subjects submitted five ideas in each context, one score for the style variable was taken as the number of ideas submitted which did <u>not</u> contain any reference to commercial factors, and is here designated the "science style score"; the other, the "commercial style score" was the number of ideas with a commercial quality. The effect of the context on each of these scores was analyzed separately, by calculating the proportion (of those subjects who had different style scores) whose scores were higher in the context antithetical to that style. For the science style score, this proportion was .125 (4 out of 32) and for the commercial style score .148 (4 out of 27). Calculating the binomial probability, both proportions were significantly different from .5, the proportion to be expected by chance: $P = .00001$ for science style; $P = .00015$ for commercial style. And the number of subjects submitting more than one commercial idea in the industrial context was significantly greater ($P = .0013$), as well as the number of subjects submitting fewer than four scientific ideas ($P = .00025$), as shown by McNemar's test for correlated proportions (Ferguson[8a]). The proportion of double-zero originality scores was possibly greater ($P = .07$) among those who submitted more commercial ideas in the industrial context than among those who submitted the same number in both contexts.

Various possible relationships between the style and originality or the difference of originality scores between the two contexts were examined, but only two were found to approach significance. When the number of science ideas was dichotomized

4 + 5 and < 4*, and compared with originality scores of 0 and > 0 in the industrial context, the value of χ^2 was 3.685 ($.025 < P < .05$, one-tailed); similar comparison with originality difference-scores in the non-industrial context gave an exact probability of .09. A one-tailed test is appropriate in the former case because the result is consistent with that for the non-industrial context (for which Fisher's exact test is one-tailed), and with the general pattern of results reported here, namely that those with zero originality scores tended to submit fewer scientific ideas, and those whose originality scores were greater in the non-industrial context produced more scientific ideas. No relationship was found between originality and the commercial style score.

Those who scored zero for originality in both contexts did not differ from other subjects in the number of science style ideas submitted in either the industrial or the non-industrial context (Kolmogorov-Smirnov test; $P = .2$) or in the difference between their style scores in the two contexts (Mann-Whitney test; $P = .7$). The former result is not directly contradictory to the relationship between the number of ideas submitted and zero score in the two contexts separately, but the lower level of significance could conceivably be due to the fact that the Mann-Whitney and Kolmogorov tests have less

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* These numbers were selected because they gave the most nearly equal division.

power than X^2.

There was no relationship between the effects of the context on style and originality (Fisher's exact test, P = .38). That is, subjects who submitted more scientific ideas in the scientific context were no more or less likely to have a higher originality score in that context than in the other.

There was no difference in ATIS score between those who scored 4 or 5 and those who scored less than 4 for science style in the industrial context($t < 1$).

4. Studies at Western

Before the research at UBC, reported above, two small studies were made at Western Washington State College, which are of peripheral interest.

In the first, arrangements were made for third and fourth year science students to take two tests of 'creativity' in class, and to be handed a 16-item version of the ATIS questionnaire for them to complete and return. The two tests were Anagrams and Unusual Uses, as described by Barron[5]. In the first, subjects had five minutes in which to write down as many words as they could construct from letters of the word GENERATION. The score on the test was computed by allotting 1, 2 or 3 points for each word of five or more letters, other than certain words given by nearly all of the subjects (viz., ration, nation, great, train, genera, in this sample of science students). Scores for other words were on the basis of their frequency in the sample, as follows:

1 point: eaten, grate, ratio.

2 points: atone, anion, enter, greet, grant, groin, grain, negation, negro, orate, inert, region, tenor.

3 points: all other words ot five letters or more.

In the second test, subjects were asked to write down as many uses as they could think of for "A BRICK". The ideas submitted were scored one point each if they were realistic, involved only <u>one</u> brick (many subjects suggested such uses as "to build a wall with") and could not reasonably be placed in a category given by 8 or more subjects (out of 81 for this test). For each test, a subject's score was the sum of the scores for each word or idea submitted.

The inter-rater reliability of the tests was not measured, since this has been done previously (Barron, op. cit.) for Unusual Uses ($r = .77$) and is presumably not dependent on subjective judgment for Anagrams.

Scores on the two tests were found to correlate to the extent of $r = .338$ (d.f. = 73; $P = .004$). Barron (op. cit.) reports that the two tests correlate respectively .62 and .60 with a composite creativity score made up of a weighted sum of six such tests. It would appear therefore that they should correlate to the extent of .372 with each other, which is in reasonable agreement with the observed correlation reported above (.338). The only finding of any relevance to the present report was that a composite score made up of the sum of the subject's standardized scores on the two tests correlated to the extent of $r = .228$ with ATIS score (d.f. = 35; $P = .18$); this does not indicate a significant relationship. Had more than half the subjects returned the ATIS questionnaire, a more significant result might have been obtained, though presumably the amount of variance accounted for by the correlation would still have been small (about 7 per cent).

A second study was in fact an indirect attempt to obtain volunteers for the group experiments which had finally to be abandoned. A questionnaire was handed out in class which asked for a subject's specialty, his chosen career (teaching, technical sales, industrial research and academic research were given as choices) and his rating of his own creativity. The 'sales line' of the questionnaire was then presented in the form of a suggestion that the subject had probably never had his scientific originality measured and would like to do so, and an invitation to take part in a "rating session" that was being arranged.

The results showed no difference in subject specialty, career choice or self-rated creativity, between those who wished to take part in the tests and those who did not.

Those who had chosen a career in industrial research rated themselves higher on creativity than did those who had chosen academic research or teaching ($X^2 = 4.28$, d.f. = 1; $.02 < P < .05$), and by using data on ATIS and creativity which were available from the previous study at Western for some of the subjects (data could only be traced for those who wrote their names on the returned questionnaires as volunteers) it was found that these subjects may in fact have had greater measured creativity ($t = 1.67$; d.f. = 11; $.05 < P < .10$). This possibility is supported by the fact that for the 15 subjects whose composite creativity score was available, there was a significant relationship of measured to self-rated creativity ($F = 4.86$; d.f. = 1,14; $P < .05$).

Measured and self-rated creativity was less but not significantly so for biology and zoology students than for physicists and chemists (cf. the results reported above for UBC graduates).

Finally, an incidental result from a small-groups study carried out at Western, using sociology students as subjects, suggested that subjects who regarded themselves as non-conformists tended to have higher ATIS scores ($r = -.253$; $P = .08$, two-tailed, or .04 if a one-tailed test is applied, on the basis that the result is consistent with what would be expected of pure science-oriented subjects, even though in this case the subjects were sociology students).

The lack of any difference in measured creativity between those who wished to take part in the tests and those who did not supports the previous conclusion that the results of the study of science graduates may be accepted as representative of non-respondents as well as respondents.

All the results reported here are summarized in the next section.

5. Summary of quantitative results

Note: Many of the results listed below have been included in order to show that _no_ relationship existed between the relevant variables.

	P*
30-item attitude schedule: discrimination:	
Pure vs. Applied Science	$>.05$
Economics vs. Commerce	$\gg .05$
Pure _or_ Applied Science vs. Economics _or_ Commerce	$<.01$
Overall discrimination	.05
16-item ATIS scale: discrimination:	
Science (Pure and Applied) vs. Commerce	$<.001$
Pre- and Post-follow-up respondents: differences:	
Scientific Originality (S.O.) (Industrial Context)	.8
S.O. (Non-industrial Context)	.8
S.O. Difference between contexts	$>.9$
Proportion of double-zero S.O. scores	.6
ATIS score	$>.4$
Proportion not submitting any ideas	.087

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* Probability of the obtained value of the relevant statistic.

	P
Assessment of Scientific Originality:	
Within-rater agreement, $r = .88$	$\ll 10^{-12}$
Between-rater agreement, $r = .58$	.000 05
Difference between $r = .58$ and $r = .88$	.000 001
Between-rater dichotomous agreement, $r_{tet} = .85$	.00037
Between-rater agreement: degree of originality for non-trivial ideas, $r = .156$	.4
S.O. score vs. style:	
industrial context	$> .4$
non-industrial context	$> .5$
food	$> .4$
clothing	.95
Correlation of S.O. score with external criterion:	
Higher S.O. scores for M.Sc. than Ph.D. students:	
chemists	.3
physicists	.1
Effect of context:	
Number of ideas submitted	.254
S.O. score (extended) reduced in industrial context	$.005 < P < .01$
Number of subjects scoring less in industrial context	.001
Number of zero reduced scores greater in industrial context	.026
Number of zero extended scores greater in industrial context	.017

	P
<u>Effect of context:</u>	
(Continued)	
Number of scores below pooled median greater in industrial context	.042
Relation of S.O. difference score and S.O. (non-industrial) for non-double-zero scorers	.126
Number of subjects submitting fewer scientific ideas in industrial context vs. number submitting more	.000 01
Number of subjects submitting more commercial ideas in industrial context vs. number submitting fewer	.00015
More scientific ideas submitted in non-industrial context	.00025
More commercial ideas submitted in industrial context	.0013
Effect on style vs. effect on S.O.	.38
More double-zero S.O. scores among those submitting more commercial ideas in industrial context	.07
ATIS score vs. effect on S.O. score	.3
Ideas of higher originality proportionately less frequent in industrial context	.3
Interaction effect of ATIS and level of originality upon S.O. difference scores	$>.5$
<u>Relations among style, originality, attitude and other variables:</u>	
ATIS scores higher for S.O. double-zero scorers: true for biological and physical sciences separately	.005

Relations among style, originality, attitude and other variables: (Continued)	P
Smaller variance of ATIS scores for double-zero scorers	$<.01$
Proportion of double-zero scorers higher for biological than for physical sciences	.074
ATIS score vs. S.O. (reduced score): Industrial context	$>.25$
Non-industrial context	$.10 < P < .25$
Number of science ideas greater for non-zero scorers on S.O.(industrial)	$.025 < P < .05$
(non-industrial)	.09
Number of science ideas less for S.O. double-zero scorers	.2
Number of science ideas vs. ATIS score	$>.2$
General creativity vs. higher ATIS score, r = .23	.18
Subjects choosing industrial research vs. academic career: higher self-rated creativity	$.02 < P < .05$
higher measured creativity	$.05 < P < .10$
Self-rated vs. measured creativity	$<.05$
Non-conformist self-image vs. higher ATIS score (sociology students)	.04

6. Theory, discussion and conclusions

The research reported here was designed not primarily to test a theory, but to answer questions of fact as a basis for any meaningful attempt at theory building. Nevertheless, the selection of variables for study in relation to originality was not haphazard, but was based on implicit theoretical conceptions which will now be made explicit. The first possibility that was anticipated as a framework for interpreting any observed effect of problem context on scientific originality was a form of dissonance theory, the central postulate of which in the present case would be that performance on an intellectual task is impaired by dissonance between an individual's values relevant to the task and values implicit in the definition of the task. Thus, a scientist who believed that the goals of science should not be of a commercial nature would not perform as well on a problem requiring originality specifically in the context of a commercial value system. A reasonable hypothesis in that case would seem to be: <u>The stronger an individual's orientation toward the values of 'pure science', the greater the adverse effect of a commercial context upon his performance in tests of those aspects of scientific thinking to which such values were relevant</u>*. But this hypothesis

* It is not specified whether the hypothesis should be applied to the 'convergent' (logico-deductive) aspects of scientific thinking, since these were not the concern of the present research.

would appear to be refuted by the lack of any observed association between ATIS scores and the difference between the extended S.O. scores. If such a dissonance theory were applicable, one would expect that for those having a pure-science orientation, the conflict between their own value system and that implicit in the industrial problem-context would be the greater and hence also the effect on their originality.

A second possible theory was that for the creative scientist, regardless of his own attitude toward industry, the commercial aspect of the industrial problem context acts as a constraint upon the expression of creativity, because of the implication that acceptance of ideas produced by the individual is not unconditional, but dependent upon certain commercial criteria being met. To the extent that the creative individual values autonomy, this conditionality would be expected to be perceived as a constraint. In that case it would be hypothesized that: The greater the originality shown in an unrestricted context ('pure science' in the present case), the greater the restraint perceived in and hence the greater the adverse effect of the conditionality implicit in a commercial context. But no significant relationship was found between originality in the pure science context and the originality difference score, whilst the lack of any significant tendency for the number of more original ideas to be reduced proportionately more than that of the less original ideas supports the conclusion that the effect of the context was unrelated to the subject's level of originality, as well as to his attitude toward industrial science.

A third possibility was that both of the previously considered theories would apply simultaneously, with the effect of the context being dependent upon both originality and attitudes of individuals, the two variables having a cumulative effect. In fact, however, there was no difference between the originality difference scores for subjects having ATIS scores above and below the median when this comparison was made at above-median and below-median levels of originality. This rules out the possibility that the apparent absence of any effect of either originality or attitude could have been due to an <u>actual</u> effect being observed by interaction between the two variables, which was unlikely in any case, since the postulated effects of both variables were in the same direction.

A fourth possibility would be that diminished scientific originality in the industrial context was the result of a belief on the subject's part that ideas acceptable to industry are relatively 'safe' and conventional, as well as commercially worthwhile. In the industrial problem-context, those subjects who were willing to conform to what they construed as the requirements of the situation would then produce ideas having those characteristics. This theory would predict an association between commercial style and diminished originality in the ideas produced: whether this association would tend to be manifested in each idea or merely in each subject is a moot point, but one would expect it to show in one form or the other. In fact, the results showed no association in either form between the difference scores for style and scientific originality, nor any association of commercial style with lowered originality, especially in the industrial context, where this theory would predict such an association.

But a fifth theory, also based on conformity, is at least consistent with the possible association (P = .07) observed between scoring zero for originality in both contexts, and submitting more commercial ideas in the industrial context. This result supports, at a low level of significance, the *post hoc* hypothesis that: *Individuals having low scientific originality tend to conform with an implied expectation that they produce commercial-type ideas, more than do individuals of greater originality*. Subjects with double-zero scores would be those having the lowest level of originality, and according to the view of the creative individual presented in the Introduction, would be most likely to conform to the implied requirements of the industrial context and produce ideas of a commercial type. Having no originality capable of being measured by the tests and rating procedure used here, these subjects would not show the association between the difference scores for style and originality predicted by the previously considered theory. But there was nevertheless a reduction in rated originality amongst subjects other than those who scored zero in both contexts, and this phenomenon remains unaccounted for by any of the theories considered. Conformity, involving both style and level of originality, would appear not to fit the results for these subjects, since there was a negative association (though not significant; $P = .19$) between commercialism and originality, i.e. those who produced more commercial ideas in the industrial context tended to show greater originality in that context. If such a result could be duplicated on a larger sample of subjects, with an acceptable level of significance, it might be considered in relation to the data on self-rated creativity at Western, namely that science students choosing a career in industrial research had higher self-rated creativity, and probably higher measured creativity ($.05 < P < .10$) than those choosing an academic career(including research).

The two results together suggest that there exists a sub-type of science student whose level of originality is not reduced, or is increased, when producing ideas of a commercial type in response to an industrial problem. With only six subjects in the present sample showing this type of response, there is little possibility of discovering much more about it, but it was found that none of the six was a biological student (for which the probability is .08). It would be predicted that subjects having this presumably applied science orientation would have lower ATIS scores, but this was not true of the four chemists in this group of six, though it was of the two physicists. The latter had scores of 13 and 16, compared to a mean of 24.7 for the remaining physics graduates. The probability of two such extreme scores in the same direction consistent with the hypothesis is only .01, so that despite the very small numbers involved, it may be true, at least for physicists, that there exists a small proportion of subjects relatively strongly oriented toward industrial values, who exhibit greater originality when conforming to the norms implied by a problem presented in an industrial context.

Thus for these two physicists, a dissonance theory similar to that considered first would appear to fit the data, except that the dissonant value system would be that of non-industrial science. But it is difficult to accept that a pure-science context should be regarded as having an "adverse" effect, considering that even the most applied scientist is immersed in a professional group whose values and traditions are predominantly those of "science for its own sake". There are, of course, alternative heroes and legends in the tradition for those of an applied scientific orientation to take as reference standards, but these are almost certainly predated and outweighed by those of pure science. Nevertheless, the data show that for a very small proportion of the present sample, scientific originality is higher in a context that is in accord with the subjects' own attitudes toward applied science. At least for this type of subject, it would seem to be preferable to rephrase the dissonance hypothesis, shifting the semantic emphasis as follows: Some individuals' performance in creative intellectual activity is enhanced in contexts having reference to values which are consonant with those individuals' own values. The fact remains, however, that for the majority of subjects in the present study there was no evidence that such a consonance (or dissonance) theory was applicable.

At this point in the discussion, it is very obvious that one conclusion to be drawn from this exploratory study is that there is a considerable diversity of types of response to tests of scientific originality. By accepting results which in some cases are of a low order of statistical significance, it is possible to delineate three possible types of subject with different patterns of response.

First is what may be called the 'uncreative pure scientist', who produces only commonplace or unspecific ideas in either an industrial or a non-industrial test situation, tends to be a biological scientist, to have a relatively high ATIS score and to be a member of a group that is relatively homogeneous in showing a pure science orientation. About 50 per cent of biological science graduates may be of this type and 20 per cent of physical scientists.

Second is the 'creative applied scientist', who is likely to be a physicist or chemist and to show more originality in an industrial context, where the ideas he produces tend to be of a commercial type, than he does in a non-industrial context. About 20 per cent of physical scientists may be of this type (22 per cent in the present sample).

Amongst the remaining subjects (about 50 per cent of this sample), who may be designated the 'creative pure scientists' and who had lower creativity scores in the industrial than in the non-industrial context, there was, as in the larger group, no association (r = .01) between ATIS score and S.O. difference score. The probabilities associated with the tendency of these subjects to submit more commercial ideas in the industrial context and more scientific ideas in the non-industrial context were .11 and .046 respectively, both of which are much less significant than the comparable values for the whole sample (.0013 and .00025). It would seem, therefore, that while these subjects were affected adversely by the industrial context as regards their originality, they were affected less than other subjects as regards the type of idea they produced, especially in their relative lack of any tendency to conform to the implied requirements of the industrial context by producing more commercial ideas.

A possible framework in which to order these diverse types of response would be that of reference groups and individual role concepts, though it would appear that these can provide only a descriptive terminology, rather than a dynamic theory in the present case. A purely role-concept theory of scientific originality would stand in marked contrast to a psychological view of originality as an inherent ability of the individual, the manifestation of which is dependent upon situational factors. The extreme role-concept approach would appear to be that the individual behaves consistently with what he believes to be appropriate to the interaction between his environment and his own role as he perceives it. We would then say that the scientist who is less original in an industrial context is so because of his <u>belief</u> that a "good" scientist can only produce "pure" science (to use the over-simplified, 'all-or-nothing' terminology appropriate to a belief that is presumably non-rational, its relevance to the facts never having been examined by the actor in the situation).

Conversely, the small minority of subjects in the present study who had a strong applied science orientation and were more original in the industrial context were so because they believed this to be consistent with the role of an applied scientist. For the substantial proportion of subjects who had zero originality scores in both contexts and a strong pure science orientation, one might, very tentatively, suggest that they were affected even by the 'restrictions' inherent in a test of originality as such, irrespective of the specific contexts and values intrinsic to the test, This is to postulate that these subjects would have been found by some other means to have measurable originality, but that this was not manifest in the Problems and Solutions test. There was no evidence either for or against such a view from the present study, if the small correlation of .23 between ATIS and general creativity found at Western is discounted, since the probability of such a value was .18 with the small number of subjects that were involved.

It would, in conclusion, appear to be the case that the reported results do not allow an objective choice to be made between the alternative theoretical frameworks by a role-concept approach and a view of originality as an inherent, but situationally dependent, ability differing quantitatively amongst individuals. The operational distinction between the two theories seem to be i) that the role-concept theory postulates no upper limit to the level of originality which the individual may reveal, given a situation ideally consonant with his values, except that which is inherent in his conception of his role. It would seem to follow from the extreme statement of this view that all scientists are potential Einsteins or Newtons, lacking only the right situation <u>or</u> a belief in their own potentiality; ii) that the inherent ability concept postulates the mechanical operation of a psychic process, in which subjectively perceived features of a situation automatically produce a certain intellectual effect.

Probably the correct view lies somewhere between the two extremes, with individuals having characteristically different levels of originality (possibly modifiable over time, as well as situationally), dependent upon more or less conscious concepts of each individual's actual, ideal and potential roles, based upon his belief in the attainability and legitimacy of patterns of behaviour (e.g. of occupying at the same time the roles of "creative scientist" and "applied scientist") derived by reference to historical and contemporary 'significant others' and 'group-myths' (e.g. "Science is the pursuit of knowledge for its own sake"), in the field of science.

Summary of conclusions

The conclusions drawn from the main and subsidiary studies of scientific originality and the preliminary study of attitudes toward industrial science were as follows:

i) There was an overall highly significant effect of an industrial problem context on rated scientific originality.

ii) There was an even more significant tendency for science graduates to produce ideas of a commercial nature in the industrial more than in the non-industrial context.

iii) Over the sample as a whole, these two effects were not significantly associated.

iv) Detailed analysis of the results indicated that at least three types of scientist might be distinguished in this sample, though the statistical basis for some aspects of this typology was not as rigorous as might be the case with a larger sample. The three types were:

a) The 'uncreative pure scientist', who obtains a zero score for originality in both contexts, tends to be a graduate of the biological sciences and to have a pure science orientation. He produces more commercial ideas in the industrial context.

b) The 'creative applied scientist', who is likely to be a chemist or physicist and shows more originality in the industrial context, where he also produces significantly more commercial ideas.

c) The 'creative pure scientist', who scores less for originality and produces fewer scientific ideas in the industrial context, but shows less tendency than the other two types to produce more commercial ideas in that context.

v) As far as adverse effects of an industrial context are concerned, type (a) present no problem, since their originality is zero in both cases: they can be easily fitted into the picture presented in the Introduction of the creative person as non-conformist, or, by contrast, the uncreative person as readily conforming to the implied norms of a situation. Types (b) and (c) are, as it were, the two sides of another coin: each shows its highest originality in the situation which presumably best conforms to its own attitudes toward the ideal nature of science, though this is borne out in their ATIS scores only in the case of the two physicists in the 'applied science' group. The possibility of there being scientists with an applied orientation who perform optimally as regards scientific originality in the industrial context is supported by the association of higher measured and self-rated creativity among science students intending to make a career in industrial research.

vi) Probably the most surprising result of the study of originality was the general lack of association between originality or the effect of context on originality and measured attitudes toward industrial science, <u>except</u> for the observation that those scoring zero in both contexts had distinctly <u>higher</u> ATIS scores. This was the more surprising because these subjects were conformist, in that they produced more commercial ideas in the industrial context, and it had been found previously (though for sociology students, not scientists) that higher ATIS scores were associated with a non-conformist self-image. Although biologists tended to have higher ATIS scores and a disproportionately large number of double-zero originality scores, the association of these two variables was found to hold for both biological and physical scientists. This result is certainly one that should be investigated in any sequel to the research reported here.

vii) As regards attitudes favouring or opposing commercialization of industrial science, it was found that criterion groups of pure and applied science, economics and commerce students were distinguished, at a low level of significance, by a battery of thirty items referring to such attitudes. The low level of overall significance was entirely due to the close similarity between the two science groups and between the economics and commerce groups. When the former were combined and compared with the commerce group, the degree of discrimination rose to a highly significant level for the original battery of thirty items. A set of weights for the sixteen most discriminating items was calculated to form a scale which appeared, from the responses of these criterion groups, to measure the extent to which subjects approved of scientific research being directed toward commercial and industrial goals. All the results of this phase of the study were consistent with what had been hypothesized beforehand, except the unanticipated finding that the commerce group was much less homogeneous in its attitude scores than were the science and economics students. Their responses to items which had been constructed in pairs aimed at the same fifteen topics from opposite points of view were also less internally consistent. These results were thought to be related to the lower level of professionalization, and consequently of group concensus on relevant issues, among those entering a career in business, compared to the well-established professional status of the scientist and the economist.

In general, the results of the study supported the idea that scientists view science differently from those whose job will include determining scientific research policy in industry, and that this disparity has a significant effect on scientific thinking in relation to industrial problems.

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APPENDIX I

STATEMENTS USED IN THE ATIS SCALE (ATTITUDES TOWARD INDUSTRIAL SCIENCE)

1. Science is basically the application of everyday common sense to the solution of practical problems.(VIII)
2. The formulation of new explanatory theories is a more important aspect of science than the discovery of new facts. (IIIB)
3. A series of short, unrelated research projects is likely to yield more worthwhile scientific results than a single extended project lasting the same total time. (VIA)
4. A scientist cannot anticipate in detail what methods and apparatus may be needed to solve a particular research problem. (II)
5. Industrialists who provide financial support for scientific research are justified in demanding that its results be of value to themselves. (I)
6. Scientific research can produce good results in a hurry, just like any other industrial tasks that sometimes have to be completed urgently. (VI)
7. The best man to head a research group in industry is one who is more concerned with basic, theoretical science than with economic and administrative matters. (III)
8. The best scientific research cannot be judged by commercial or economic standards. (I)
9. Before allocating money for scientific research, an industrial concern is justified in requiring its scientists to forecast the sort of results they are likely to obtain.(VA)

10. The basis of the rapid development of modern science has been the theoretical insights of a relatively small number of scientists, rather than the more routine experimental work carried on by the majority of industrial scientists. (VIII)
11. In general, the most worthwhile scientific results are likely to be obtained only from research that has unlimited time available for its completion. (VIA)
12. To be of much use to industry, any theory a scientist develops should be capable of being understood by a non-scientist in terms of everyday familiar facts. (IIIB)
13. If scientists stopped developing new theories for a few decades and concentrated on just discovering factual knowledge of nature, there would soon be nothing worthy of the name of science left in existence. (IIIB)
14. A scientist working for industry can't be expected to predict with any certainty the outcome of a particular piece of research. (IV)
15. Scientists in industry should devote most of their attention to research problems that are of direct economic significance. (I)
16. No scientist should have to earn a living doing research controlled by the profit-seeking motives of industry. (I)
17. The course of an industrial research programme should be planned in advance, just like any other industrial activity. (II)

18. Much of the scientific effort expended on developing new theories would be better applied to solving practical problems. (IIIB)
19. Scientific research is more than just the methodical application of scientific knowledge and technique.(VIII)
20. An industrial research scientist cannot do his best work if the company's policy is such that his research may be terminated in the event of adverse economic conditions developing. (VII)
21. The possible economic value of his results should be of no concern to an industrial research scientist. (I)
22. Science advances more by the slow, cautious modification of established principles than by an occasional major theoretical reformulation. (VB)
23. Scientists should concentrate for a few years on deriving the practical benefits from existing scientific knowledge, not keep looking for new discoveries. (IIIB)
24. The very best science is a quest for an understanding of nature, irrespective of any commercial implications. (I)
25. Non-scientists, familiar with industrial and economic problems, should have the ultimate control over the course of scientific advance. (I)
26. The fact that his work may increase the profits of the industrial concern supporting his research can often be an important incentive to even the best research scientist.(I)

27. If an industrial concern only gives 'conditional' approval to research projects, in case it is later necessary to discontinue them in the event of unfavourable economic conditions, there is no reason why this policy should adversely affect the work of research scientists in the company. (VII)
28. Even scientific research results which are incomprehensible to non-scientists can be of great commercial value to industry. (IIIA)
29. A scientist cannot be expected to do his best research work when an industrial concern is urgently demanding results in order to develop and market them ahead of a competitor. (VIB)
30. A research scientist in industry should look for new factual data and techniques, rather than try to develop new theories. (IIIB)

APPENDIX II

RESEARCH MATERIALS FOR
A SMALL-GROUPS STUDY
OF SCIENTIFIC ORIGINALITY.

Outline of the experimental design and procedure

Purpose

The purposes of this experimental design are briefly as follows:

1. To find whether scientific originality correlated with scores on creativity tests.
2. To see to what extent summated originality scores in a group test could be predicted from the scores of group members on an individual test of scientific originality.
3. To study the effect of an industrial context upon scientific originality under two leadership conditions, (a) where the leader might be expected to shield the group from the norms implied in the problem situation; (b) where his own views would be consonant with those implied in the problem situation and he would be expected to transmit their effect to the group.
4. To see whether any effect as under (3) was greater, the higher the rated creativity and scientific originality of subjects.
5. To examine the dependence of leader-rejection upon dissonance amongst the values of the group-members, the leader and the task situation.

Design

The design is a two-factor analysis of variance fixed effects model with provision for between-cell matching on one additional variable, and covariance adjustment for one other.

The two treatment factors are:

1. the context in which a test of originality is applied;
2. the pure-scientific or commercial orientation of the leader appointed to each group.

The variable for which between-cell matching is possible is the mean attitude score (attitudes toward industrial science) for each group of four subjects.

The variable for which covariance adjustment may be made is the mean creativity score for each group.

Procedure

Subjects are seated at tables randomly in groups of four, having been told that they are to take some tests of individual scientific originality, without reference to group participation. Each table has a reference letter printed on a card laid at the centre of the table, as does each subject before his own place at the table. The four subject reference-letters are the same for each table. It is anticipated that twenty groups would be a sufficient number for statistical purposes, and that all would be run simultaneously. Each subject has a stack of IBM cards beside his place, on which he will write ideas in the tests of scientific originality.

Instruction Book I is placed before each subject and is opened and completed page by page, the experimenter giving the signal to turn over when the appropriate time has elapsed. The sequence of pages is self-explanatory. Page 1 is intended to provide a control for the degree of acquaintance among subjects in each group. Pages 2 and 3 are standard tests of general creativity. Pages 4 - 7 comprise the ATIS scale of attitudes toward industrial science, in a shortened self-score form. After completing it, each subject enters his ATIS score on the Group Scores Form lying on his group's table; these are collected by the experimenter, totalled and rank-ordered on the totals. Assuming that the number of groups present is divisible by four, the rank-ordered forms are dealt out into four piles in randomized order, e.g. in the sequence Pile 3, 1, 4, 2; 1, 4, 2, 3; etc. The four piles correspond to the four treatment combinations, hence the procedure achieves a randomized matching, which should reduce the error variance without infringing the randomness requirement underlying the analysis of variance design. Allocating a group to a particular treatment combination determines whether the highest or lowest scoring individual on the ATIS test shall be designated as group leader, and whether the group shall take the group Problems and Solutions test in the industrial or the non-industrial context.

While the above procedure is being carried out by the experimenter and his assistants, the subjects complete the individual Problems and Solutions test on Pages 8 and 9. The

Group Scores Forms are then handed back to each of the tables, with Instruction Book II, on the first page of which the subjects are informed that a leader has been appointed. (Note: the letter J is entered on each scale before Instruction Book II is handed out, according to whether the test is to be taken by that group in the industrial or the non-industrial context. It is suggested that a score of about 26 is suitable for the position attributed to the judging panel). On the alternative versions of Page 2 are statements alleged to define the judges' attitudes toward industrial science. Page 3 describes the method by which each group collectively carries out the test, and the role played by the leader. It is intended that a record of the number of ideas which subjects pass to their group leader, and the number he approves, should be used in the subsequent analysis as measures of leader- and group-acceptance of each other. The statement defining the method of scoring is intended merely to elicit the desired response from subjects: it is not the method of scoring actually to be used in the analysis, where a simple summation of individual scores for <u>all</u> ideas produced (whether or not accepted by the leader) is intended to be employed.

After completing the group test, leaders are asked to place in an envelope all the IBM cards filled in by their group, and bring it to the experimenter's table. They are then seated at tables removed from their groups and complete Form L (intended merely to occupy their time while their group members complete Form M without the possibly inhibiting presence of their group leader, about whom they are asked to express their opinion in that form).

S.O./ A.T.I.S.

RATING

SESSION

*

INSTRUCTION BOOK I

*

EACH PAGE IS A SEPARATE STAGE IN THE RATING PROCEDURE, SO PLEASE DO NOT OPEN THE BOOK OR TURN ANY PAGE UNTIL ASKED TO DO SO.

The reference letters for your table are( )( )( )
Your own reference letter is( )

Turn over the card at the center of your table and copy the reference letters from it into the spaces in the top line on this page, above.

Now turn over the card in front of you and copy the reference letter from it into the space in the second line above.

Please answer the following questions.

1. What is your subject major?............................
2. Which year are you in? Sophomore( )
   Junior ( )
   Senior ( )
3. Sex. Male( ) Female( )
4. How well do you know the people at your table? (This information is needed to compute one of your ratings. It serves as a correcting factor). Put a check-mark in one of the spaces under each person's letter in the following table. Leave blank the spaces under your own letter.

	His/Her letter.			
	T	M	K	R
Never met before				
Acquaintances				
Know each other quite well				

RATING 1A

ANAGRAMS.

When the instructor says to begin, write down all the anagrams you can think of, having 5 OR MORE LETTERS, in the word GENERATION. An anagram contains only letters selected from the given word, but arranged in any order. People's names are not counted. Any words of foreign origin must be of accepted usage in English-speaking countries. You will have five minutes.

The word is G E N E R A T I O N.

RATING 1B

UNUSUAL USES.

When the instructor says to begin, write down all the most original, but realistic uses you can think of for ONE BRICK. You will have five minutes.

Write each idea on a separate card.

ATTITUDES TOWARD INDUSTRIAL SCIENCE

Industry is one of the major institutions in contemporary society; and scientific research is one of the essential bases of modern industry, without which the economic growth of industrial societies could scarcely be maintained. So the nature of scientific research in industry is potentially of considerable interest to students of pure and applied science.

What is the ideal nature of science in industry, in your opinion? Should scientific research concentrate on the practical problems faced by industry, and seek economically worthwhile solutions to these problems; or should it pursue the basic goals of fundamental pure science, irrespective of economic considerations; or perhaps it should be somewhere between these two alternatives? What do you think? You can express your opinion about this topic by indicating your response to each of the ten statements overleaf, as follows.

If you disagree strongly with a particular statement, put DD against it. If you disagree, but don't feel strongly, put D. If you strongly agree with a statement, put AA against it, but if you agree without feeling very strongly, put A. Finally, if you really have no opinion either way about a small minority of the statements, or are unable to decide one way or the other, put O against them.

SCORING SHEET.

Calculate your own score on the A.T.I.S. rating scale using the table on the next page; you can turn this page without waiting for the instructor.

The basic principle is very simple. The items have different weights in contributing to your score and some items contribute in opposite directions because of the way they were worded.

For each item, look at your response at the extreme right of the next page and see how many A's or D's you put for it. Then look to see which side of the table on the next page to use for that particular item, and enter the number of A's or D's in the appropriate column where it says "Number of A's ( )" or "Number of D's ( )". Then multiply by the number shown in that column, leaving the other column blank for that item. If you put <u>0</u> for an item it doesn't count toward your score, so pass on to the next item.

<u>Example</u>. Suppose you put "AA" for Item 6. You would enter (2) in the space provided in the S (left hand) column and multiply it by 3, to give 6, which you would write after the equals sign. Similarly for all the other items.

Then add the columns separately, note which total is greater, and write down the difference between the larger and the smaller.

Look overleaf and see whether you understand how to work out your score. The calculation is actually very easy if you follow it step by step.

Of course, it's extremely important that you don't alter any of the responses you have already written down.

	"S" COLUMN	"C" COLUMN
ITEM	NUMBER OF.....	NUMBER OF........
1	A's: ( )x1=.....	D's: ( )x1=.....
2	D's: ( )x1=.....	A's: ( )x1=.....
3	A's: ( )x4=.....	D's: ( )x4=.....
4	D's: ( )x5=.....	A's: ( )x5=.....
5	D's: ( )x5=.....	A's: ( )x5=.....
6	A's: ( )x3=.....	D's: ( )x3=.....
7	D's: ( )x2=.....	A's: ( )x2=.....
8	A's: ( )x2=.....	D's: ( )x2=.....
9	A's: ( )x2=.....	D's: ( )x2=.....
10	A's: ( )x2=.....	D's: ( )x2=.....
	TOTAL (S column)	TOTAL (C column)

<u>If the two totals are not equal:</u>

Which column has the <u>greater</u> total?
Enter C or S here

Subtract the smaller total from the greater and enter the difference here

<u>If the two totals are exactly equal:</u>
Write 0 as your score here

"C" means that your attitudes toward science in industry resemble those of students majoring in Commerce or Economics more than do the attitudes of most Pure and Applied Science students.

"S" means that your attitudes are toward the other extreme amongst Pure and Applied Science students, opposite to that symbolized by "C".

The highest score you could get in either direction would be 54, but for science students a score above 30S or below 3S is quite unusual.

NOW LOOK AT THE <u>GROUP SCORES FORM</u> ON YOUR TABLE

STATEMENT Nº	RESPONSE
1.	....
2.	....
3.	....
4.	....
5.	....
6.	....
7.	....
8.	....
9.	....
10.	....

S. O. RATING 1

PROBLEMS AND SOLUTIONS (A)

In this test of scientific originality, you will be presented with a description of a scientific situation of rather wide scope, and you have to think of problems that could be investigated in that situation, and also of ways in which solutions to those problems might be found. In order to get a score for originality on any idea that you write down, it must first of all be realistic and relevant to the situation.

The problems and solutions you suggest need not all be related to one another. For example, you could suggest an original problem, but not how to solve it; or you could merely refer to a well-known problem, which wouldn't add to your originality score, but you could put forward a really new way of solving it, and this would add to your score. Write each idea on a separate card, because each card can be scored only once.

You will have 3 minutes to read the description of the test situation carefully and to start thinking of problems and solutions. The instructor will tell you when to start writing. Then you will have 5 minutes to write down the ideas you think are the most original.

THIS IS AN INDIVIDUAL TEST. PLEASE DO NOT TALK TO ANYONE.

PROBLEMS AND SOLUTIONS (A)

Imagine you are an independent research consultant. A Foundation seeks your advice on establishing a program of research to develop new kinds of FOOD PRODUCTS, for which they have available a large grant from various sources, including government, industry and consumer organizations.

What problems would you suggest should be studied, and how might they be solved?

Table (A) (G) (Y)

GROUP SCORES FORM.

Pass this form around the table and each enter your own score (number; and letter C or S) in the spaces provided.

Your individual reference letter	Your score	
	Number	Letter
R		
K		
M		
T		

When you have done that, please wait until the instructor tells you to turn to the next page in the Instruction Book.

ENTER THE REFERENCE LETTERS FOR YOUR TABLE HERE

ENTER YOUR OWN REFERENCE LETTER HERE

S.O./ A.T.I.S.

RATING

SESSION

*

INSTRUCTION BOOK II

GROUP TEST

The next rating consists of a test of scientific originality similar to the one you have just completed, but to be done by the four people at your table as a group.

Each group will have a leader, chosen on the basis of your scores on the attitude test. The reference letter of the leader of your group is encircled on the GROUP SCORES form just handed back to your table by the instructor. Look on it to see who is the leader of your group.

The first thing for the leader to do is to plot all four scores from the Group Scores form on the scale below in his own Instuction Book and then in the books of the three members of his group, using an encircled dot labelled with each person's reference letter, like the "J" already marked on the scale. Write "LEADER" against the leader's score, so that the relation of his score to those of the members of his group is apparent. Note carefully that "S" scores go on the right hand side of the scale, "C" scores on the left. Pass your Instruction Books to your group leader one at a time to have the attitude scores plotted on the scale.

50 40 30 20 10 0 10 20 30 40 50

"C" Scores — "S" Scores

The "J" already marked on the scale stands for "JUDGES". It is the average score of three industrial research executives who have agreed to act as a panel for assessing the ratings of students attending these sessions. It has been marked on the scale so that you will know what sort of ideas are likely to get top grades. As a further assist in that direction, overleaf is a statement expressing, interms of the attitude schedule you just completed, the judges' views about science in industry. Read it carefully a couple of times to get an overall impression of the judges' attitudes toward the kind of problem you will be doing next.

"The basis of the rapid development of modern science has been the theoretical insights of a relatively small number of scientists, rather than the more routine experimental work carried on by the majority of industrial scientists. Even scientific theories which are incomprehensible to non-scientists in terms of everyday familiar facts can be of great value to industry, and for that reason science should be under the ultimate control of scientists, since they understand its purpose. One aspect of the control of science which may have adverse effects on a scientist's work is when a company's policy is such that his research may be terminated in the event of unfavorable economic conditions developing. The best scientific research cannot be judged adequately by economic or commercial standards."

What is your immediate response to this summary of the views held by the three assessors for the next test? Put an "X" on the following scale to indicate your opinion.

Completely disagree	0	Completely agree

"It is the more or less routine experimental work carried on by the majority of industrial scientists that has led to the rapid development of modern science, rather than the theoretical insights of a relatively small number of scientists. To be of much use to industry, any theory a scientist develops should be capable of being easily understood by non-scientists, who should have the ultimate control over the course of scientific advance, because they are familiar with industrial and economic problems. One essential aspect of such control is the termination of an industrial scientist's research in the event of adverse economic conditions developing, but the anticipation that this may happen should not affect the quality of his research work. Scientific research, even the very best, can be judged by economic or commercial standards."

What is your immediate response to this summary of the views held by the three assessors for the next test? Put an "X" on the following scale to indicate your opinion.

Completely disagree	0	Completely agree

S.O. RATING 2

GROUP TEST.

As in the individual test of scientific originality which you completed previously, each person will write down the ideas he thinks of, using a separate card for each idea.

But for the group test there is one essential difference, in order to make it a valid test of the contribution made by each person to the overall scientific originality of the group. The difference is that if you want an idea you have written down to count toward the group score, it must be given to the group leader, one of whose functions is to decide which ideas are good enough (i.e., Relevant, Realistic and Original) to be put forward on behalf of the whole group. If he decides that an idea is good enough, he will put a check-mark (✓) and his initials on the front of the card (the side printed with rows of numbers) and pass it to the other members of his group to read, so that it can stimulate other original ideas in the group. The card will then be put in the box at the center of your table, when everybody has read it.

If the group leader does not think an idea is relevant and realistic and original enough to be put forward on behalf of the whole group, he will write an "X" and his initials on the side of the card where the rows of numbers are printed (in the space above the rows), and put it straight into the box without passing it around the group.

If you are not the group leader you can, if you wish, put any of your cards straight into the box yourself, but they won't count toward the group score in that case, only toward your own individual score. But each person's OVERALL score on this test is largely determined by the score of his group: this is especially true of the leader, since a considerable part of his time will be taken up with assessing the ideas of members of his group.

The group leader himself will not put any of his own ideas straight into the box: a second essential function for him as leader is to pass around the group all the ideas he himself thinks of and writes down. There is no need for him to initial and check-mark his own cards.

In this test everything is done in writing, since verbal discussion would disturb other groups in their work.

As before, a scientific situation will be presented to you and you will have three minutes to read it carefully and start thinking of problems and solutions. The instructor will tell you when to start writing and you will then have seven minutes for the test.

Leaders especially should re-read these instructions to make sure they know what to do.

PROBLEMS AND SOLUTIONS (B)

Imagine you are an independent research consultant. A Foundation seeks your advice on establishing a program of research to develop new kinds of CLOTHING MATERIALS, for which they have available a large grant from various sources, including government, industry and consumer organizations.

What problems would you suggest should be studied, and how might they be solved?

RESULTS.

Please write on the attached envelope your name and the address where the results can be sent to you in about three weeks.

Now write your group reference letters and your individual reference letter here.

Group letters ( )( )( )

Individual letter ( )

Family name..............................

First names..............................

When you receive your results, they will show your standings on the tests, relative to others taking them, represented as a percentage; e.g., 95% would mean that your score was higher than 95% of the whole sample of students on that test; 25% would mean that your score was better than only one-quarter of the total sample. Your results will be returned to you on this form.

TEST	YOUR STANDING
1. General creativity	
2. Scientific originality (Individual score)	
3. Scientific originality (Group task)	
4. Attitudes toward industrial science	

Note that Test 4 is a test of attitudes, not abilities, so a score of 95% is no 'better' than a score of 5%; they simply have different meanings. A score below 50% means that your attitude toward the ideal nature of science in industry is more like that of students majoring in commerce and economics than is that of the average science or engineering student.

Remember that these tests are not infallible, and also that both attitudes and abilities are likely to change over time, especially if you deliberately set out to cultivate a particular attitude that you think necessary for your chosen career. Even aptitudes, such as scientific originality, can probably be increased by practice.....or diminished by neglect!

L

S.O./ A.T.I.S.

RATING SESSION.

Before coming to the final stage of the rating session, the following information is needed to compute your rating on the S.O. Test Number 2.

Enter the reference letters from the cover of your Instruction Book here

Group [ ][ ][ ]

Self [ ]

Indicate your response to each of the following questions by putting an "X" at an appropriate position on each of the scales.

1. Did you enjoy being leader of your group?

Liked it very much	0	Disliked it very much

2. Which member of your group do you think should be the leader for the next stage?
   Circle one of these four letters: T M K R

3. To what extent did you try to get your group to produce ideas of the sort that the panel of judges would be most likely to accept?

Not at all	Completely

4. Do you think your group did as well as you would have liked it to on this test?

Yes	No

5. Did you have to reject more ideas than you had anticipated, because they were not good enough to count for the whole group?

Yes	No

6. What sort of attitude should a leader have for a task such as this, when the results are to be assessed by a panel of judges like the ones in this case?

High "Commerce" Score	0	High "Science" Score

M

S.O./ A.T.I.S.

RATING SESSION

Before coming to the final stage of the rating session, the following information is needed to compute your rating on the S.O. Test Number 2.

Enter the reference letters from the cover of your Instruction Book here

Group [ ][ ][ ]

Self [ ]

Indicate your response to each of the following questions by putting an "X" at an appropriate position on each of the scales.

1. Before starting the next stage of the session, how satisfied are you with the leader appointed for your group?

Completely dissatisfied	0	Completely satisfied

2. Which member of your group do you think should be the leader **for** the next stage?

   Circle one of these four letters T M K R

3. To what extent did the leader try to get the group to produce ideas of the sort that the panel of judges would be most likely to accept?

Not at all	Completely

4. How often did you find that you disagreed with your group leader's decision to accept or not accept an idea, either your own or someone else's?

Never	Always

5. Would your group do better or not as well on this kind of test with another member as leader instead of the present one?

Much better	Same	Much worse

6. What sort of scientific attitudes should a group leader have for a task such as this, where the results are to be assessed by a panel of judges like the ones in this case?

High "Commerce" Score	0	High "Science" Score