PERS 280

THE BLACK WORKER'S UNDERSTANDING OF ABSTRACT TECHNICAL CONCEPTS RELEVANT TO INDUSTRY

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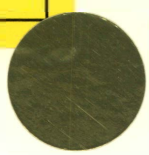

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M C Kellerman

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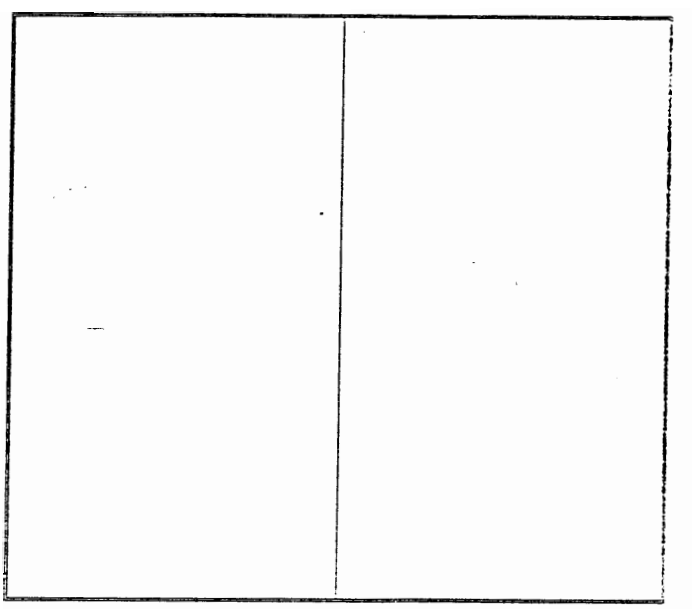

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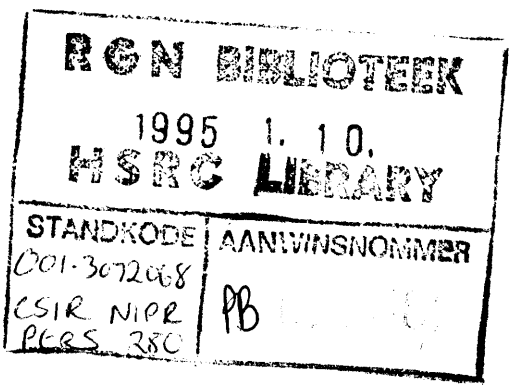

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ABSTRACT

This study was undertaken to determine the Black industrial worker's comprehension of abstract technical concepts which are of cardinal importance in the South African Western industrial setting.

A test comprising multiple-choice items, the Concept Understanding Test, was designed as measuring instrument. A sample of 121 subjects (Blacks: n=95, Indians: n=15 and Whites: n=11) was tested at two organisations. Achievement on the Concept Understanding Test increased progressively with educational level, and a significant correlation was found between level of education and performance on the test.

The conclusion was that the cultural background of the Black worker does not necessarily constitute a restricting factor in his comprehension of abstract technical concepts relevant to Western industry. However, level of education is important.

OPSOMMING

Hierdie studie is onderneem om die Swart nywerheidswerker se begrip te bepaal van abstrakte tegniese terme wat in die Suid-Afrikaanse Westerse nywerheidsituasie van kardinale belang is.

'n Toets bestaande uit veelvoudige-keuse items, die Konsepbegripstoets, is as meetinstrument ontwerp. 'n Steekproef van 121 persone (Swartes : n = 95, Indiërs : n = 15 en Blankes : n = 11) is by twee organisasies getoets. Prestasie op die Konsepbegripstoets het progressief toegeneem met opvoedkundige vlak, en 'n beduidende korrelasie is gevind tussen opvoedkundige vlak en prestasie op die toets.

Die afleiding is dat die kulturele agtergrond van die Swart werker nie noodwendig 'n stremmende faktor is by sy begrip van abstrakte tegniese terme wat in die Westerse nywerheid ter sake is nie. Die vlak van skool-opvoeding is egter belangrik.

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1. BACKGROUND TO THE STUDY

Black labour is of extreme importance to South African industry. Compared to Whites the majority of these workers have a low literacy level and a backlog in their knowledge of science and technology.

Darlington (1969)[1] explains this backlog in terms of the cultural evolution of the Black, as compared to the trend elsewhere, eg. in Europe. In his view science and technology could only take root in a meaningful way once man settled down as an agriculturalist. Once this stage was reached production of surplus foods was possible, which in turn led to the development of commerce and home industries, and ultimately to the development of organised industry. This process occurred earlier in Europe and Asia than in Africa. The development of the Black peoples of Africa was further retarded, however, by such factors as disease and illness, enslavement and wars (Darlington, 1969)[2].

Black workers, especially those with low literacy levels, have to absorb a substantial number of new concepts when entering Western industry. In view of the literacy problem, training to convey these concepts to the Black worker, has to rely a great deal on verbal communication. Whether this verbal communication is in fact effective in narrowing the gap in the Black worker's knowledge and understanding of technological concepts, is open to question.

The languages of the Blacks in Africa, although in many respects extremely graphic and descriptive, to a large extent lack precise scientific terms for many industrially relevant concepts, especially in their active vocabulary. This lack of scientific terminology is mentioned by several authors (Case, 1972[3]; Wallman, 1972[4]; Seretlo, 1973[5]). This serves as a further indication that less emphasis was placed on advanced science and technology in Black culture. This means that the Black worker entering Western industry may be less familiar, or even unfamiliar with concepts relevant to Western industry. The question therefore arises as to whether the Black worker attaches the same meaning to these concepts as the White Westerner. Wallman (1972)[6] illustrates how even something as objective as measurement can cause fundamental disagreements, and that it would be inaccurate to accept that agreement exists regarding the meaning of many words in cross-cultural communication.

Knowledge and understanding of at least some basic scientific and technological concepts are, however, necessary in Western industry. Miscomprehension may affect the learning process and consequently productivity. The conveyance of concrete concepts (e.g. machine parts) usually causes no problems, since such objects can be easily pointed out visually. Abstract concepts, however, e.g. pressure, gravity, etc., are normally not so easy to illustrate and further abstractions are needed to explain their meanings. Miscomprehension may thus easily occur.

The implications of cultural differences as regards verbal communication, therefore, could be of significance to success in training. In view of the present situation where increasing numbers of Blacks will have to be trained for industry, particularly those with a lower literacy level and a rural background, there is a distinct need to determine the extent to which problems exist in this field.

2. AIMS OF THE STUDY

This study is aimed at investigating the Black industrial worker's comprehension of abstract technological concepts which are of cardinal importance in Western industry. Depending on the outcome it will be decided whether a modified training approach is necessary.

To keep the scope of the study within reasonable limits, (i) only literate Black industrial workers were initially included in the sample, assuming that, if literates should experience problems with abstract technological concepts, this would be even more true for illiterates; (ii) not all possible concepts would be tested, but only those appearing most frequently or which were most important in training programmes. These concepts would be chosen in consultation with training personnel or would be drawn from specific training programmes. Since different industries emphasize different concepts, the tests for the participating industries would have to be organisation-specific, although a great deal of overlapping would be possible.

3. DESIGN OF THE CONCEPT UNDERSTANDING TEST

3.1 Measurement approach

Several methods were considered for the measurement of comprehension of the abstract technological concepts.

Free verbalisation was rejected, as a testee might comprehend the meaning of a given term, but be unable to verbalise it. In addition, such a procedure is very time consuming. The use of questions based on drawings was also rejected since this would involve the perception of pictorial material as an additional variable. (The problems which Blacks encounter in perception of pictorial material are discussed in greater detail in Kellerman 1976[7]).

Multiple choice response items seemed to be most appropriate, and this method was therefore, adopted. Geometrical concepts were also tested according to this format by means of two-dimensional geometrical figures.

3.2 Selection of items

Lists of abstract technical terms used in the training programmes of White and non-White artisans (welders, fitters, electricians, motor mechanics, brick layers) were made available by the Industrial Training centre of the South African Sugar Association of Mount Edgecombe, Natal. From these terms 31 items were chosen to compile the Concept Understanding Test (CUT), which was applied at this centre. The complete list of concepts tested appears in Tables 1 - 4 (Appendix B). Each item tested one concept only.

The training unit of African Explosives and Chemical Industries (AECI) at Sasolburg, OFS, provided training programmes for Black and White chemical operators, from which fifty terms were selected for this version of the Concept Understanding Test (refer Tables 5 - 16, Appendix B).

3.3 Preparation of items

In the preparation of items an attempt was made to test real insight and understanding of concepts, for example the concept of volume was tested as follows:

> I have a mug which contains 1 litre of milk, and a bottle which contains 1 litre of cream. This means that the milk and the cream have the same:
>
> (a) Weight
> (b) Length
> (c) Measurement
> (d) Volume
> (e) Gravity

Since the CUT was not designed as a formal selection instrument, the items were accepted solely on the basis of content validity.

3.4 The test

The Concept Understanding Test is a paper-and-pencil test which can be administered as an individual or group test, with no time limit. The 31-item version applied at the Training Centre of the S A Sugar Association, consisted mainly of electrical and geometrical concepts and some general abstract concepts. The 50-item version applied at AECI mainly covered chemical and geometrical concepts, with some general abstract concepts.

4. THE SAMPLE USED IN THE STUDY

The Industrial Training Centre of the South African Sugar Association at Mount Edgecombe, and the Midland factory of African Explosives and Chemical Industries at Sasolburg, provided subjects for the study. All available subjects were tested. The subjects were divided into three groups of differing educational levels for analysis of the data. For comparative purposes Indians and Whites were also included in the sample.

4.1 Group 1 (S A Sugar Association)

This group consisted of 9 Black subjects* and 15 Indians who were tested before their training commenced. No post-training test was administered due to financial restrictions. Four of the Indians were being trained as welders, three as electricians, two as mechanics and six as fitters. Two of the Black subjects were being trained as mechanics and seven as fitters.

The Biographical data for Group 1 are presented in Table 1, p.5.

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* Initially there were 18 Black subjects, but half of them indicated that they did not have sufficient command of either of the official languages, and these subjects were thus eliminated.

TABLE 1: BIOGRAPHICAL DATA FOR GROUP 1

	Mean age	Mean education	Home language	Home area
BLACKS (n = 9)	32,22 SD = 9,51	Std. 4,4** SD = 1,13	Swazi : 5 Zulu : 3 Shangana-Tsonga : 1	Komatipoort : 4 Malelane : 2 Pongola : 2 Stanger : 1
INDIANS (n = 15)	33,93 SD = 8,66	Std. 5,5** SD = 1,81	English : 10 Tamil : 3 Eng/Tamil : 1 Eng/Hindu : 1	Durban

**Statistically significant difference at $\alpha = 0,05$. In view of the small sample, the Mann-Whitney Test was used as non-parametric alternative to the t-test for two independent samples (refer Huysamen, 1976)[8].

TABLE 2: BIOGRAPHICAL DATA FOR GROUP 2

	Mean age	Mean education	Home language	Home area
BLACKS (n = 23)	26,00 SD = 4,18	Std. 9,2* SD = 1,41	S-Sotha : 12 Tswana : 6 Xhosa : 2 Tsonga : 2 Zulu : 1	Vaal Triangle : 21 Johannesburg : 1 Pretoria : 1
WHITES (n = 11)	26,62 SD = 6,64	Std. 8,7* SD = 1,24	English : 2 Afrikaans : 9	Sasolburg

*Statistically significant difference at $\alpha = 0,05$ (Mann-Whitney Test)

TABLE 3: BIOGRAPHICAL DATA FOR GROUP 3

Size of group (n)	Mean age	Mean education	Home language	Home area
7	29,86 SD = 5,34	Std. 6,3 SD = 0,76	S-Sotho : 3 N-Sotho : 1 Zulu : 1 Xhosa : 1 Ndebele : 1	Vaal Triangle : 5 Potgietersrus : 1 Tsolo (Transkei) : 1
18	24,22 SD = 3,56	Std. 8,2 SD = 0,47	S-Sotho : 5 N-Sotho : 1 Zulu : 6 Xhosa : 1 Tswana : 5	Vaal Triangle : 17 Viljoenskroon : 1
9	26,11 SD = 4,51	Teachers Certificate	S-Sotha : 6 Tswana : 3	Vaal Triangle : 8 Warm Baths : 1
47	24,34 SD = 3,14	Std. 9,3 (Combined stds. 8-10) SD = 1,05	S-Sotho : 14 N-Sotho : 1 Zulu : 5 Xhosa : 2 Tswana : 7	Vaal Triangle : 41 Viljoenskroon : 1 Dundee : 1 Bloemfontein : 2 Frankfort : 1 Pietersburg : 1
29	24,41 SD = 2,91	Std. 10	Tswana : 7 S-Sotho : 14 N-Sotho : 1 Zulu : 5 Xhosa : 2	Vaal Triangle : 24 Dundee (Natal) : 1 Bloemfontein : 2 Frankfort (OFS) : 1 Pietersburg : 1
63	25,17 SD = 3,95	Std. 9,24 (Group 3 as a whole) SD = 1,47	S-Sotho : 28 N-Sotho : 3 Zulu : 12 Xhosa : 4 Tswana : 15 Ndebele : 1	Vaal Triangle : 54 Potgietersrus : 1 Tsolo (Transkei) : 1 Viljoenskroon : 1 Warm Baths : 1 Dundee : 1 Bloemfontein : 2 Frankfort : 1 Pietersburg : 1

4.2 Group 2 (AECI)

This group comprised 23 Black subjects and 11 White subjects who were tested before being trained as chemical operators, and again after completion of their training. The time span between the pre- and post-training test varied from 7 to 10 days. The same version of the Concept Understanding Test was used before and after training.

The biographical data for Group 2 is presented in Table 2, p.5.

4.3 Group 3 (AECI)

This group totalled 63 Black subjects of whom 54 were fully-trained employees of AECI in positions such as operators, cooling floor attendants, printing assistants, raw material attendants, final examiners, senior charge hands, crane drivers, raw material handlers, packline assistants, tappers, one gas yield analyser, an outside assistant, a charge assistant, an autoclave charging assistant and a drying assistant. The periods of service of these subjects ranged from one month to five years and more. The remaining 9 subjects were job applicants. (See Table 3, p. 6)

5. DESIGN OF THE STUDY

All the subjects completed a short Biographical Questionnaire and the Concept Understanding Test. Groups 1 and 2 also completed a test of abstract reasoning ability, the so-called Figure Classification Test (FCT), designed by the NIPR. This test was administered as a control measure to determine whether any difference in achievement on the Concept Understanding Test between Black subjects and other ethnical groups could perhaps be attributable to differences in abstract reasoning ability. Group 1 did the low-level form of the FCT, and Group 2 the high-level form. Group 3 was tested mainly to determine the relationship between educational level and achievement on the Concept Understanding Test. This group therefore did not do the FCT.

The Concept Understanding Test was also administered to the subjects in Group 2 after training, but not to the subjects in Group 1 because of financial restrictions. The subjects in Group 3 were mostly fully trained employees at AECI, and therefore the CUT was administered once only to them.

The testing was done in English since all the subjects in Group 1 preferred English as testing medium, whereas in the case of Groups 2 and 3 English was the official language of the company.

6. RESULTS

6.1 Overall results

The means and standard deviations of the various groups for the Figure Classification Test and the Concept Understanding Test are tabulated in Tables 4 - 6 below.

Graphs for the frequency distributions of the scores appear in Figures 1 - 7, Appendix A.

TABLE 4: RESULTS FOR GROUP 1 (n = 24)

	FCT (36 items)	CUT (31 items)
BLACKS (n = 9)	$\bar{X}$ = 14,33 SD = 6,71	$\bar{X}$ = 9,11* SD = 4,76
INDIANS (n = 15)	$\bar{X}$ = 15,13 SD = 9,48	$\bar{X}$ = 17,13* SD = 4,97

* Significant at α = 0,05 (Mann-Whitney Test)

TABLE 5: RESULTS FOR GROUP 2 (n = 34)

	FCT (36 items)	CUT (50 items)	
		Pre-training	Post-training
BLACKS (n = 23)	$\bar{X}$ = 21,78 SD = 6,33	$\bar{X}$ = 40,70 SD = 5,82	$\bar{X}$ = 42,74 SD = 5,15
WHITES (n = 11)	$\bar{X}$ = 22,27 SD = 5,85	$\bar{X}$ = 42,18 SD = 4,87	$\bar{X}$ = 43,64 SD = 5,43

TABLE 6: RESULTS FOR GROUP 3 (n = 63) ON THE CONCEPT UNDERSTANDING TEST (50 ITEMS)

Std 6,3	Std. 8,2	TC*	Standards 8 - 10 combined (=Std. 9,3)	Std. 10	Group 3 as a whole
$\bar{X}$=23,86 SD=10,79	$\bar{X}$=37,50 SD= 4,85	$\bar{X}$=38,67 SD= 5,68	$\bar{X}$ = 41,00 SD = 4,44	$\bar{X}$=43,17 SD= 2,30	$\bar{X}$ = 38,79 SD = 7,71

* TC = Teachers Certificate

6.2 Percentages of correct responses on the Concept Understanding Test

The analyses of the correct responses to the various items in the Concept Understanding Test are presented in Tables 1 - 16, Appendix B. Table 7 indicates the percentages of items answered incorrectly by more than 50% of the subjects in the various groups. The concepts covered by these items are presented in Table 8, page 10.

TABLE 7: PERCENTAGES OF ITEMS ANSWERED INCORRECTLY BY MORE THAN 50% OF THE SUBJECTS

	GROUP 1	GROUP 2	GROUP 3				
BLACKS	77%	Pre-training: 10%	Std.6,3	Std.8,2	TC	Std.9,3	Std.10
		Post-training: 4%	48%	16%	14%	6%	4%
INDIANS	35%						
WHITES		Pre-training: 8% Post-training: 2%					

6.3 Analysis

From the analyses of the results the following observations were made:

6.3.1 No statistically significant difference was found between the results of Blacks and other ethnic groups (Groups 1 and 2) on the Figure Classification Test (the non-verbal test of abstract reasoning ability).

6.3.2 The results of the Blacks and Indians in Group 1 differed significantly on the Concept Understanding Test (abstract verbal concepts). No significant difference was found between the results of Blacks and Whites (Group 2) on this test.

TABLE 8: CONCEPTS ANSWERED INCORRECTLY BY MORE THAN 50% OF THE SUBJECTS IN THE VARIOUS GROUPS

(——Common concepts answered incorrectly by Blacks and Indians in Group 1)

(═══Common concepts answered incorrectly by all Groups)

% Answered incorrectly	GROUP 1 (n = 24)		GROUP 2 (n = 34)		GROUP 3 (n = 63)			
	Blacks (n=9) Std. 4,4	Indians (n=15) Std. 5,5	Blacks (n=23) Std. 9,2	Whites (n=11) Std. 8,7	Std. 6,3 (n=7)	Std. 8,2 (n=18)	TC (n=9)	Std. 10 (n=29)
91% - 100%	sequence vertical radius synchronise				radiation tertiary quality saturate			
31% - 90%	regulate conduction resistance alternate circuit	synchronise primary			pressure conduction primary revolution process	heat		
71% - 80%	gravity primary corrosion volume neutral polarity	sequence radius circuit oblique	PRE-TRAINING: heat POST-TRAINING: heat quality		parallel volume condensation particle revolution system		quality heat	quality
61% to 70%	right angle insulate similar oblique short circuit magnetism connect	conduction polarity volume	PRE-TRAINING: tertiary quality heat exchange	PRE-TRAINING: heat revolution POST-TRAINING: heat		pressure radiation tertiary quality heat exchange	radiation tertiary revolution	
51% to 60%	rotation vacuum	short circuit current	PRE-TRAINING: radiation	PRE-TRAINING: perpendicular quality	vertical perpendicular right angle rectangular vacuum resistance maximum heat exchange heat	resistance saturate	conduction heat exchange	heat

6.3.3 The Black subjects in Group 2 displayed a statistically significant improvement in performance on the Concept Understanding Test after training, but no significant improvement was displayed by Whites.*

6.3.4 The scores for the subgroups in Group 3 seemed to increase with educational level, and the Kruskal-Wallis test** was therefore applied to compare results of the various educational groups. The results of at least two subgroups differed significantly so that the data were further analysed by means of the Mann-Whitney test to determine which of the subgroups showed significant differences in performance (refer Table 9). Performance on the Concept Understanding Test did, in fact, increase significantly with educational level.

TABLE 9: COMPARISON OF RESULTS FOR THE SUBGROUPS IN GROUP 3

Groups compared	Calculated U-value	Critical value
Stds. 6 and 8	7	24*
Stds. 6 and TC	4	9*
Stds. 6 and 10	0	43*
Stds. 8 and TC	65,5	36
Stds. 8 and 10	83	155*
TC and Std. 10	48,5	63*

* Significant at α = 0,01 (Mann-Whitney test)

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* The Wilcoxon-test was used as non-parametric alternative to the t-testttt for related groups to compare pre- and post-training performance (refer Huysamen, 1976)[9].

** In the Kruskal-Wallis test the rationale of the Mann-Whitney test is extended to make provision for the comparison of individuals from more than two populations (refer Huysamen, 1976)[10].

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7. DISCUSSION

7.1 Group 1

The superior performance of the Indian subjects on the Concept Understanding Test could possibly be attributed to one, or a combination, of the following factors:

7.1.1 Greater familiarity with the English terms because their home language was predominantly English. The English-speaking Indians also performed better than the two Tamil-speaking subjects, although it must be mentioned here that the latter subjects had a much lower educational level than the rest of the Indian group (Class 1* and standard 3 respectively).

7.1.2 The significantly higher educational level of the Indian group.

7.1.3 The fact that all the Indian subjects lived in an urban area (Durban vicinity), whereas the Black subjects came from rural areas.

7.1.4 The fact that Indians had earlier and more intimate contact with Western science and technology, and can therefore be regarded as "more Westernised" than Blacks (Darlington, 1969[11], Hayes, Baldwin and Cole, 1970[12]).

7.2 Group 2

Both Black and White subjects in this group performed markedly better than those in Group 1. The subjects in Group 2 did, however, have higher educational qualifications than those in Group 1. In addition, a very high selection and training standard is maintained at AECI. (Candidates are screened by considering only those who comply with the requirements for a specific job for appointment, e.g. where matriculation is a pre-requisite, all non-matriculants are eliminated. Comprehensive selection tests are then administered with high cut-off points for acceptance. Workers are finally appointed only after strict induction and training programmes with high criterion standards are completed successfully.)

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* Class 1 = Grade 1 = Substandard A

Despite the significantly higher educational level of the Blacks no significant difference was found between results of the Black and White subjects. It thus seems as though the White Westerners had a slight advantage in respect of knowledge and understanding of industrially relevant abstract technical concepts.

This may be attributable to greater familiarity with Western industry amongst the Whites. The exceptionally good performance of the Black subjects does, however, indicate that at higher educational levels Black industrial workers seem just as capable as their White counterparts in understanding industrially relevant abstract technological concepts. Cross-cultural investigation at the lower educational levels is indicated.

The data for Group 2 do not support the suggestion that home language could be the determining variable in the understanding of abstract technological concepts, since neither Blacks nor Afrikaans-speaking subjects performed worse than English-speaking subjects. It must nevertheless be kept in mind that all the subjects in Group 2 had a good command of English.

Since all subjects in Group 2 lived in the Vaal Triangle, the effect of origin from rural versus urban areas could not be investigated.

7.3 Group 3

Considering the fact that the higher qualified subjects in Group 2 performed better than those with lower qualifications in Group 1, the results for Group 3 were analysed on the basis of educational level. Performances on the Concept Understanding Test increased significantly with educational level, which underlines the importance of school education.

7.4 General

The correlation between educational level and achievement on the Concept Understanding Test was determined for the whole sample by means of a Spearman coefficient of correlation (refer Table 10). A significant correlation was found between educational level and CUT-score.

TABLE 10: SPEARMAN COEFFICIENT OF CORRELATION: CUT-SCORE AND EDUCATIONAL LEVEL

Group 1 (n = 24)		Group 2 (n = 34)		Group 3 (n = 63)	
Correlation (r)	Critical value	Correlation (r)	Critical value	Correlation (r)	Critical value
0,61	0,472*	0,45	0,358*	0,67	0,295*

*Significant at α = 0,01. (The somewhat lower correlation for Group 2 is probably due to the smaller variance in the educational levels of the subjects in this group.)

8. CONCLUSIONS

8.1 Results seem to indicate that formal education is the most important variable affecting the understanding of abstract technical concepts*, although the effect of home language and urban/rural origin and Westernisation cannot be altogether eliminated before further research in these areas is conducted.

8.2 The cultural backlog of the Black industrial worker in science and technology does not constitute a stumbling block to comprehension of abstract technological concepts relevant to Western industry. With adequate schooling and training, the Black industrial worker can be assisted in his understanding and application of such concepts.

---

* This finding agrees with that made by Grant, [13,14] who carried out a study to determine the influence of urbanisation, industrial experience and formal school education on the structure of the intellectual abilities of adult Venda males. He concluded that education was the most important influence determining intellectual structure as well as ability level.

9. RECOMMENDATIONS

9.1 Training approach at lower levels.

The effectiveness of existing training programmes in promoting knowledge and understanding of abstract technological concepts for trainees at educational levels of standard 6/7 and lower, should be investigated.

Fully trained standard 6 and 7 subjects performed markedly worse than more highly educated subjects in their particular organisation, although these subjects did not necessarily fill lower positions. This indicates that a different training approach might be necessary at lower educational levels (e.g. greater emphasis on practical demonstration and trainee participation, illustration, and the possible use of simulation). Present conventional approaches seem to be satisfactory at higher educational levels.

In training courses special attention should be given to the elucidation of abstract technological concepts, especially to trainees with lower literacy levels and illiterates.

9.2 Abstract concepts referring to human aspects of work

The understanding of abstract technical concepts concerned with human aspects of work in Western industry, should be investigated. This would include concepts such as responsibility, motivation, promotion, productivity, and the like. All these concepts are of cardinal importance in improving effective use of available labour.

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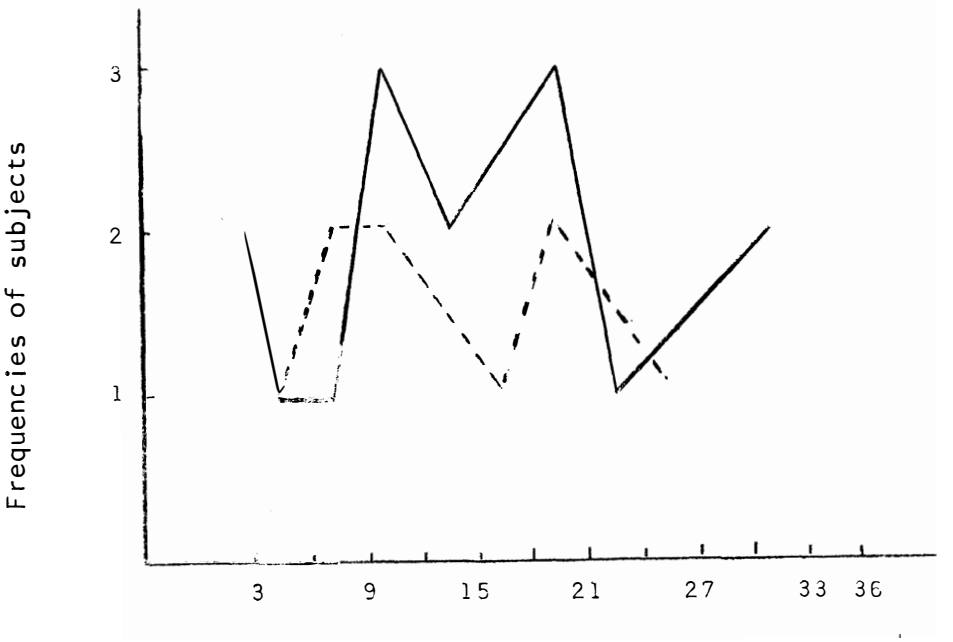
APPENDIX A

FIGURES SHOWING THE DISTRIBUTION OF SCORES FOR THE VARIOUS GROUPS OF SUBJECTS ON THE FCT AND THE CUT

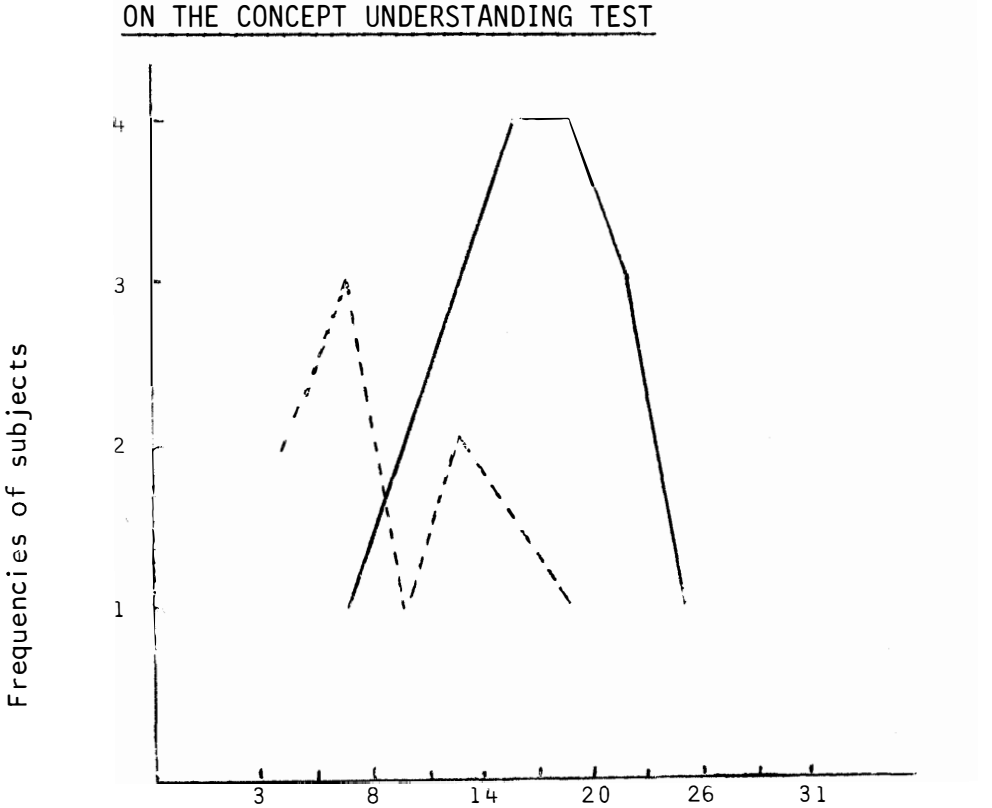
FIG. 1: FREQUENCY DISTRIBUTION OF SCORES OF BLACKS AND INDIANS (GROUP 1) ON THE FIGURE CLASSIFICATION TEST



----- = Blacks (n=9; $\overline{X}$ score = 14,3)

——— = Indians (n=15; $\overline{X}$ score = 15,1)

FIG. 2: FREQUENCY DISTRIBUTION OF SCORES OF BLACKS AND INDIANS (GROUP 1) ON THE CONCEPT UNDERSTANDING TEST



----- = Blacks (n=9; $\overline{X}$ score = 9,1)

——— = Indians (n=15; $\overline{X}$ score = 17,1)

FIG. 3: FREQUENCY DISTRIBUTION OF SCORES OF BLACKS AND WHITES (GROUP 2) ON THE FIGURE CLASSIFICATION TEST

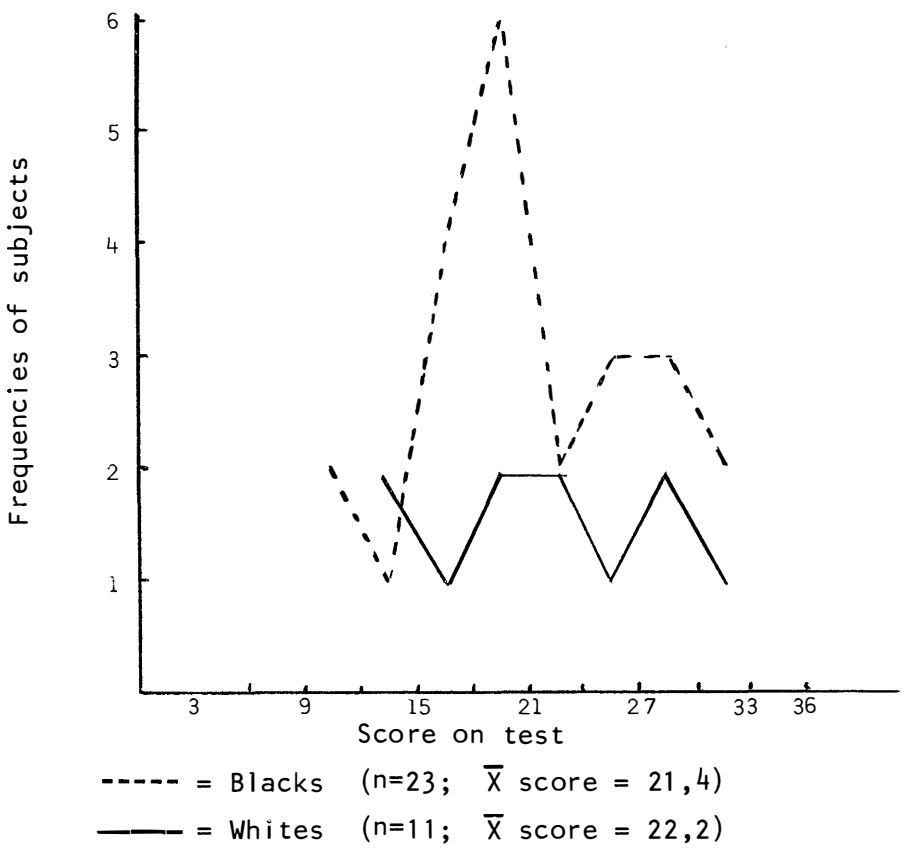
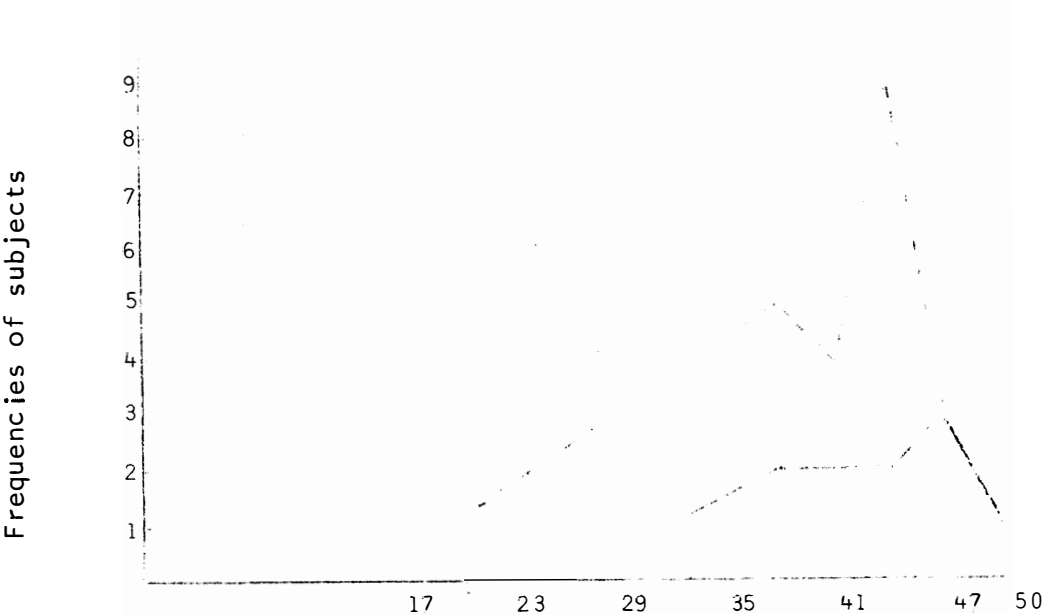


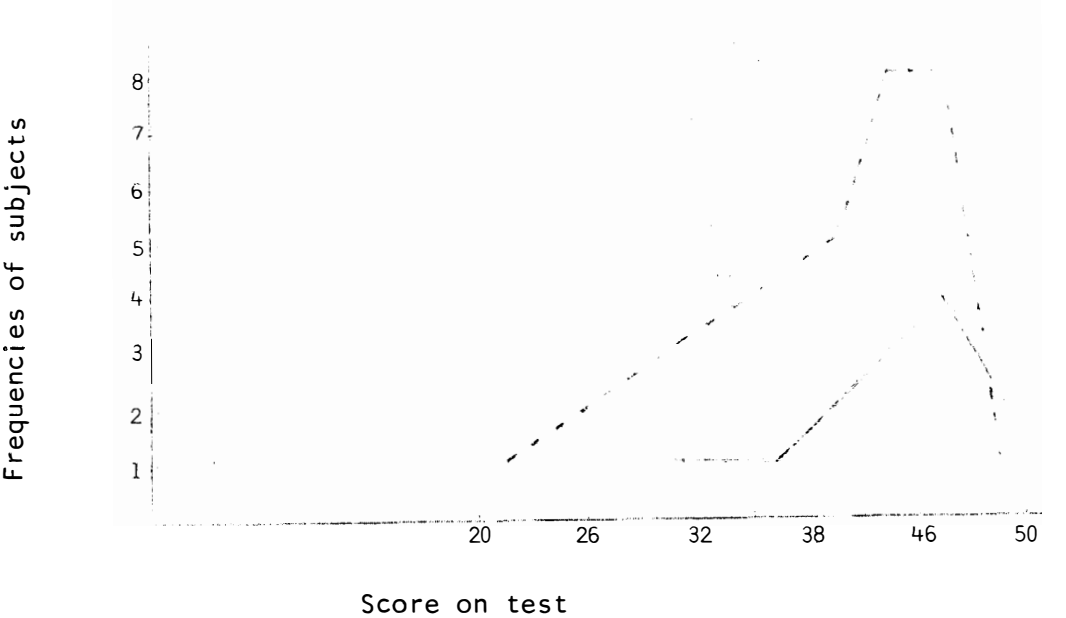
FIG. 4: FREQUENCY DISTRIBUTION OF PRE-TRAINING SCORES OF BLACKS AND WHITES (GROUP 2) ON THE CONCEPT UNDERSTANDING TEST



----- = Blacks (n=23; $\overline{X}$ score = 40,7)

——— = Whites (n=11; $\overline{X}$ score = 42,1)

FIG 5: FREQUENCY DISTRIBUTION OF POST-TRAINING SCORES OF BLACKS AND WHITES (GROUP 2) ON THE CONCEPT UNDERSTANDING TEST



----- = Blacks (n=23; $\overline{X}$ score = 42,7)

——— = Whites (n=11; $\overline{X}$ score = 43,6)

FIG 6: FREQUENCY DISTRIBUTION OF SCORES OF THE STANDARD 6,3 GROUP ON CUT (GROUP 3)

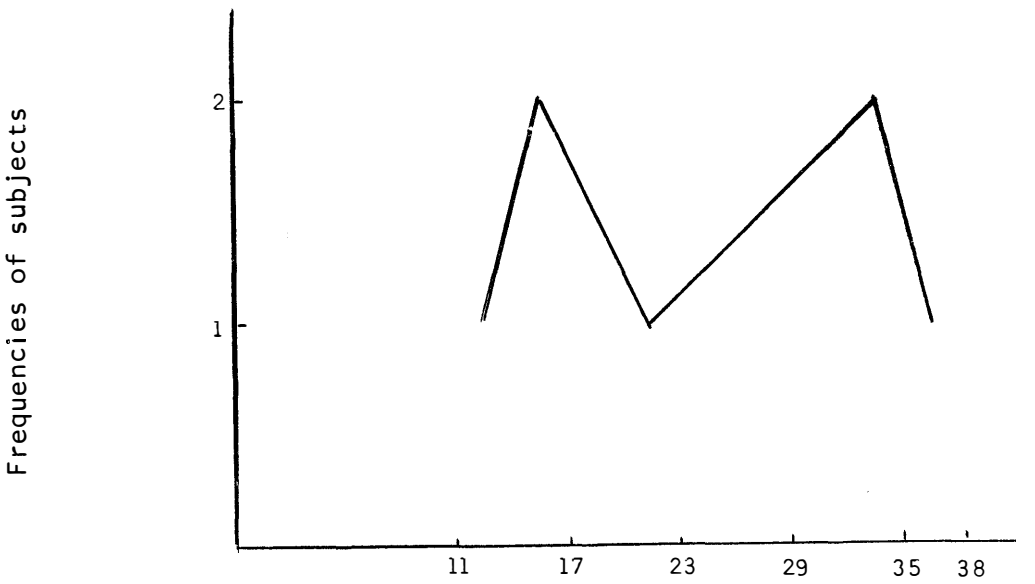


FIG 7: DISTRIBUTION ON SCORES OF THE STANDARD 8,2 GROUP ON CUT (GROUP 3)

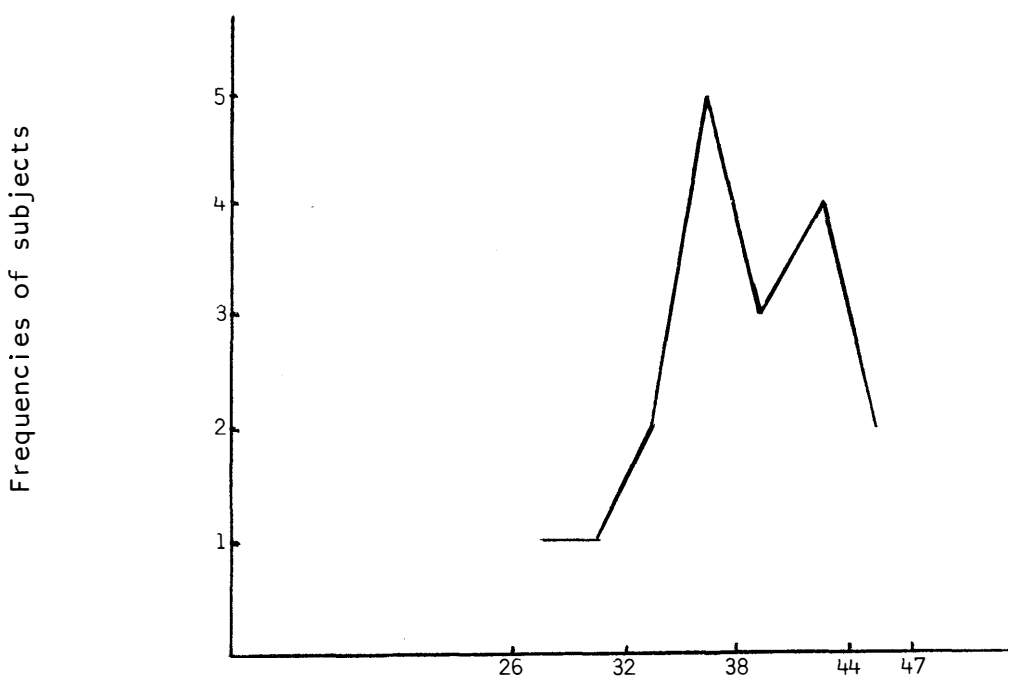


FIG. 8: FREQUENCY DISTRIBUTION OF SCORES OF THE STANDARD 10 GROUP ON CUT (GROUP 3)

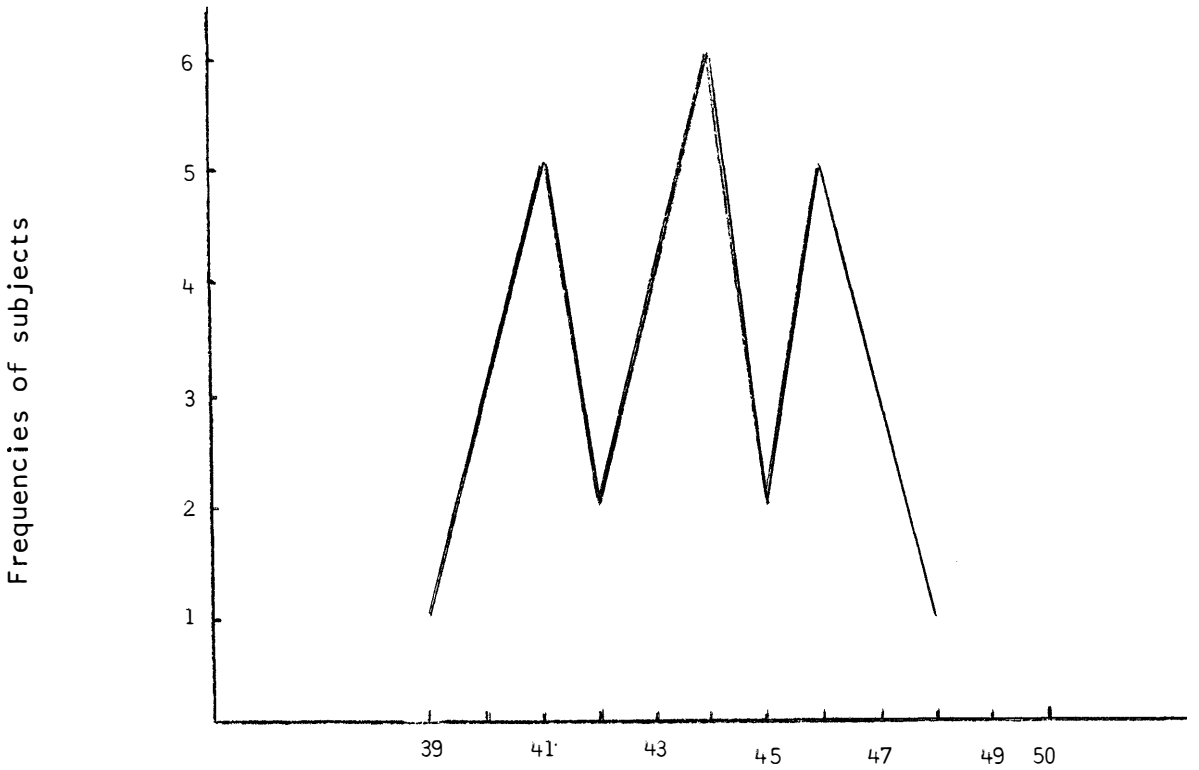


FIG. 9: DISTRIBUTION OF SCORES OF THE COMBINED STANDARD 8 - 10 GROUP ON CUT (GROUP 3)

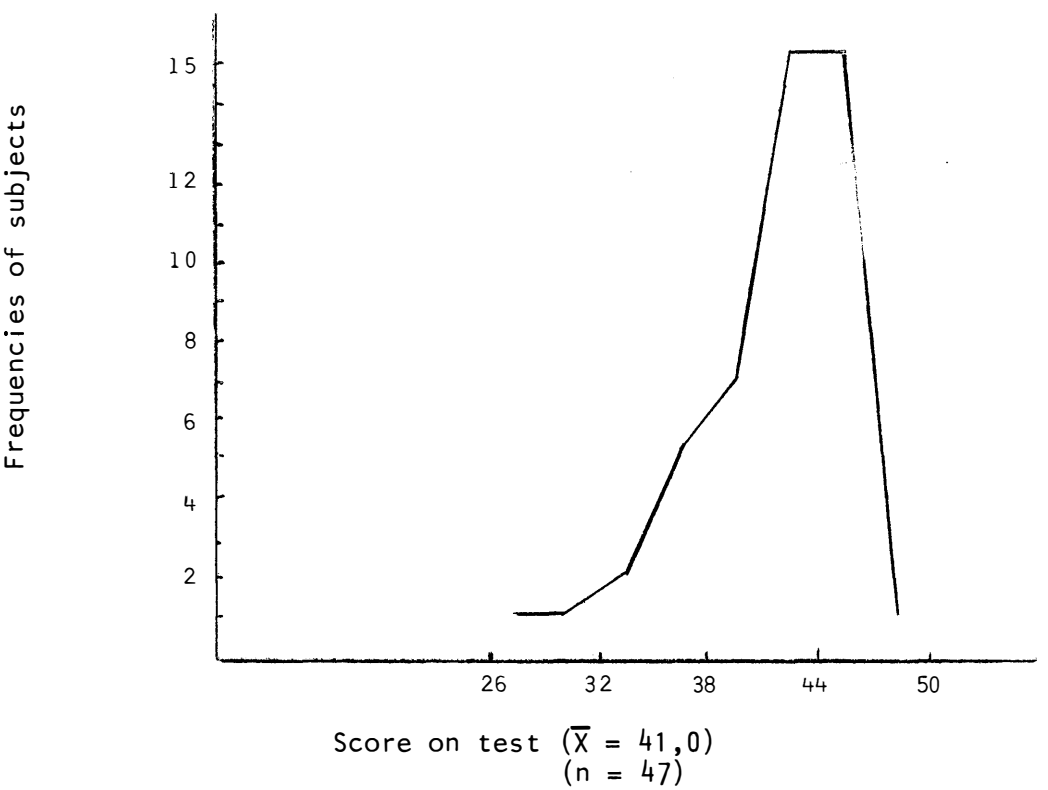
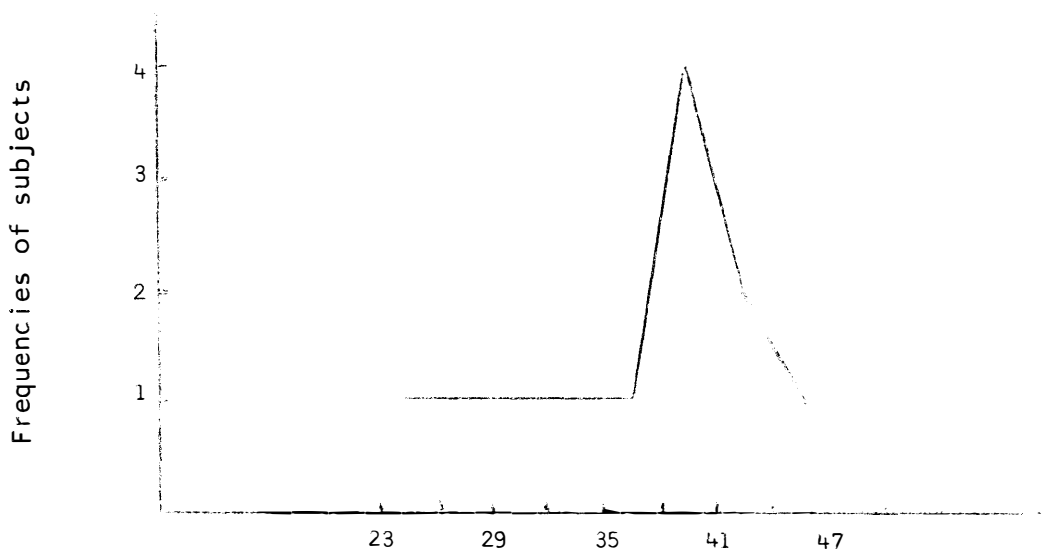


FIG. 10: FREQUENCY DISTRIBUTION OF SCORES OF THE TC* GROUP (GROUP 3)



Score on test ($\overline{X}$ = 38,7)
(n = 9)

* TC = Teacher's Certificate

APPENDIX B

PERCENTAGES CORRECT RESPONSES ON THE CONCEPT UNDERSTANDING TEST

TABLE 1: PERCENTAGE CORRECT RESPONSES FOR BLACKS AND INDIANS (GROUP 1)

Item no.	Concept	Blacks (%) (n=9)	Indians (%) (n=15)
1	pressure	56	67
2	cone	56	93
3	gravity	22	60
4	rotation	44	80
5	balance	78	87
6	primary	22	20
7	vacuum	44	53
8	corrosion	22	60
9	sequence	0	27
10	volume	22	40
11	vertical	0	60
12	right angle	33	60
13	regulate	11	67
14	oblique	33	27
15	conduction	11	33
16	radius	0	27
17	magnetism	33	67
18	insulate	33	67
19	resistance	11	53
20	short circuit	33	47
21	neutral	22	73
22	polarity	22	33
23	connect	33	60
24	alternate	11	53
25	synchronise	0	13
26	temperature	56	87
27	absorb	56	73
28	similar	33	73
29	adjust	56	73
30	circuit	11	27
31	current	56	47

TABLE 2: PERCENTAGE CORRECT RESPONSES FOR BLACKS (n=9) IN GROUP 1

% correct	Concept	
0	sequence, vertical, radius, synchronise	(4)
11	regulate, conduction, resistance, alternate, circuit	(5)
22	gravity, primary, corrosion, volume, neutral, polarity	(6)
33	right angle, insulate, similar, oblique, short circuit, magnetism, connect	(7)
44	rotation vacuum	(2)
56	pressure, absorb, cone, adjust, temperature, current	(6)
88	balance	(1)

TABLE 3: PERCENTAGE CORRECT RESPONSES FOR INDIANS (n=15) IN GROUP 1

% correct	Concept	
13	synchronise	(1)
20	primary	(1)
27	sequence, radius, circuit, oblique	(4)
33	conduction, polarity	(2)
40	volume	(1)
47	short circuit, current	(2)
53	vacuum, resistance, alternate	(3)
60	gravity, corrosion, vertical, right angle, connect	(5)
67	pressure, regulate, magnetism, insulate	(4)
73	neutral, absorb, similar, adjust	(4)
80	rotation	(1)
87	balance, temperature	(2)
93	cone	(1)

TABLE 4: PERCENTAGE CORRECT RESPONSES FOR BLACKS AND INDIANS (GROUP 1)

% correct	Blacks (n=9)	Indians (n=15)
0	sequence, vertical, radius, synchronise (4)	
11 - 20	regulate, conduction, resistance, alternate, circuit (5)	synchronise, primary (2)
21 - 30	gravity, primary, corrosion, volume, neutral, polarity (6)	sequence, radius, circuit, oblique (4)
31 - 40	right angle, insulate, similar, oblique, short circuit, magnetism, connect (7)	conduction, polarity, volume (3)
41 - 50	rotation, vacuum (2)	short circuit, current (2)
51 - 60	pressure, absorb. cone, adjust, temperature, current (6)	vacuum, resistance, alternate, gravity, corrosion, vertical, right angle, connect (8)
61 - 70		pressure, regulate, magnetism, insulate (4)
71 - 80		neutral, absorb, similar, adjust, rotation (5)
81 - 90	balance (1)	balance, temperature (2)
91 - 100		cone (1)

TABLE 5: PERCENTAGE CORRECT RESPONSES FOR GROUP 2

Item no.	Concept	Blacks (n=23)		Whites (n=11)	
		Pre-training	Post-training	Pre-training	Post-training
1	Vertical	68	91	91	91
2	Horizontal	80	91	91	91
3	Square	78	87	82	73
4	Perpendicular	74	83	45	64
5	Parallel	96	96	73	82
6	Right angle	100	100	91	100
7	Cylindrical	96	96	100	100
8	Rectangular	96	100	82	91
9	Temperature	88	96	100	100
10	Volume	60	65	100	82
11	Expand	92	100	100	100
12	Pressure	52	65	91	100
13	Condensation	88	91	82	91
14	Conduction	88	83	73	82
15	Radiation	44	61	64	82
16	Vacuum	92	91	100	100
17	Evaporation	100	96	82	91
18	Primary	80	83	91	82

Item no.	Concept	Blacks (n=23)		Whites (n=11)	
		Pre-training	Post-training	Pre-training	Post-training
19	Tertiary	40	78	64	100
20	Secondary	84	96	73	91
21	Revolution*	76	83	64	82
22	Space	92	83	100	82
23	Resistance	84	83	82	82
24	Quality	40	26	45	55
25	Current	76	78	100	82
26	Maximum	80	87	100	91
27	Atmosphere	72	87	91	82
28	Compression	96	91	100	100
29	Absorb	100	96	91	82
30	Particle	96	100	91	73
31	Saturate	72	78	82	100
32	Surface	76	70	100	100
33	Heat	24	30	36	36
34	Heat transfer	72	74	73	73
35	Circulate	92	96	100	100
36	Balance	100	100	91	91
37	Rotation	96	87	91	73
38	Revolution*	80	78	36	64
39	Gravity	92	87	100	100
40	Oxidation	80	74	82	100
41	System	92	100	82	73
42	Join	96	100	91	91
43	Weight	96	100	100	91
44	Heat exchange	40	74	64	91
45	Process	92	96	91	82
46	Flow rate	84	96	82	91
47	Automatically	100	100	100	100
48	Manually	88	91	100	100
49	Air	96	100	100	100
50	Chemical process	92	83	82	91

* Note that the concept of revolution was tested twice, albeit in a different way for the two items.

TABLE 6: PRE- AND POST-TRAINING RESULTS OF BLACKS (n=23) GROUP 2

% correct	PRE-TRAINING	POST-TRAINING
21 - 30	heat (1)	heat, quality (2)
31 - 40	tertiary, quality, heat exchange (3)	
41 - 50	radiation (1)	
51 - 60	volume, pressure (2)	
61 - 70	vertical (1)	volume, pressure, radiation, surface (4)
71 - 80	horizontal, square, perpendicular, primary, revolution, current, maximum, atmosphere, saturate, surface, heat transfer, revolution, oxidation (13)	tertiary, current, saturate, heat transfer, revolution, oxidation, heat exchange (7)
81 - 90	temperature, condensation, conduction, secondary, resistance, flow rate, manually (7)	square, perpendicular, conduction, primary, revolution, space, resistance, maximum, atmosphere, rotation, gravity, chemical process (12)
91 - 100	parallel, right angle, cylindrical, rectangular, expand, vacuum, evaporation, space, compression, absorb, particle, circulate, balance, rotation, gravity, system, join, weight, process, automatically, air, chemical process (22)	vertical, horizontal, parallel, right angle, cylindrical, rectangular, temperature, expand, condensation, vacuum, evaporation, secondary, compression, absorb, particle, circulate, balance, system, join, weight, process, flow rate, automatically, manually, air (25)

TABLE 7: PRE- AND POST-TRAINING RESULTS OF WHITES (n=11) GROUP 2

% correct	PRE-TRAINING	POST-TRAINING
31 - 40	heat, revolution (2)	heat (1)
41 - 50	perpendicular, quality (2)	
51 - 60		quality (1)
61 - 70	radiation, tertiary, revolution, heat exchange (4)	perpendicular, revolution (2)
71 - 80	parallel, conduction, secondary heat transfer (4)	square, particle, heat transfer, rotation, system (5)
81 - 90	square, rectangular, condensation, evaporation, resistance, saturate, oxidation, system, flow rate, chemical process (10)	parallel, volume, conduction, radiation, primary, revolution, space, resistance, atmosphere, absorb, process (11)
91 - 100	vertical, horizontal, right angle, cylindrical, temperature, volume, expand, pressure, vacuum, primary, space, current, maximum, atmosphere, compression, absorb, particle, surface, circulate, balance, rotation, gravity, join, weight, process, automatically, manually, air. (28)	vertical, horizontal, right angle, cylindrical, rectangular, temperature, expand, pressure, condensation, vacuum, evaporation, tertiary, secondary, current, maximum, compression, saturate, surface, circulate, balance, gravity, oxidation, join, weight, heat exchange, flow rate, automatically, manually, air, chemical process (30)

TABLE 8: PRE-TRAINING RESULTS OF BLACKS AND WHITES: GROUP 2

% correct	Blacks (n=23)	Whites (n=11)
21 - 30	heat (1)	
31 - 40	tertiary, quality, heat exchange (3)	heat, revolution (2)
41 - 50	radiation (1)	perpendicular, quality (2)
51 - 60	volume, pressure (2)	
61 - 70	vertical (1)	radiation, tertiary, revolution, heat exchange (4)
71 - 80	horizontal, square, perpendicular, primary, revolution, current, maximum, atmosphere, saturate, surface, heat transfer, revolution, oxidation (13)	parallel, conduction, secondary, heat transfer (4)
81 - 90	temperature, condensation, conduction, secondary, resistance, flow rate manually (7)	square, rectangular, condensation, evaporation, resistance, saturate, oxidation, system, flow rate, chemical process (10)
91 - 100	parallel, right angle, cylindrical, rectangular, expand, vacuum, evaporation, space, compression, absorb, particle, circulate, balance, rotation, gravity, system, join, weight, process, automatically, air, chemical process (22)	vertical, horizontal, right angle, cylindrical, temperature, volume, expand, pressure, vacuum, primary, space, current, maximum, atmosphere, compression, absorb, particle, surface, circulate, balance, rotation, gravity, join, weight, process, automatically, manually, air (28)

TABLE 9: POST-TRAINING RESULTS OF BLACKS AND WHITES: GROUP 2

% correct	Blacks (n=23)	Whites (n=11)
21 - 30	heat, quality (2)	
31 - 40		heat (1)
41 - 50		
51 - 60		quality (1)
61 - 70	volume, pressure, radiation, surface (4)	perpendicular, revolution (2)
71 - 80	tertiary, current, saturate, heat transfer, revolution, oxidation, heat exchange (7)	square, particle, heat transfer, rotation, system (5)
81 - 90	square, perpendicular, conduction, primary, revolution, space, resistance, maximum, atmosphere, rotation, gravity, chemical process (12)	parallel, volume, conduction, radiation, primary, revolution, space, resistance, atmosphere, absorb, process (11)
91 - 100	vertical, horizontal, parallel, right angle, cylindrical, rectangular, temperature, expand, condensation, vacuum, evaporation, secondary, compression, absorb, particle, circulate, balance, system, join, weight, process, flow rate, automatically, manually, air (25)	vertical, horizontal, right angle, cylindrical, rectangular, temperature, expand, pressure, condensation, vacuum, evaporation, tertiary, secondary, current, maximum, compression, saturate, surface, circulate, balance, gravity, oxidation, join, weight, heat exchange, flow rate, automatically, manually, air, chemical process (30)

TABLE 10: PERCENTAGES OF CORRECT RESPONSES FOR BLACKS GROUP 3, CUT (n=63)

Item No.	Concept	Std 6,3 (n=7)	Std 8,2 (n=18)	Std 10 (n=29)	TC (n=9)	Combined (n=63)
1	Vertical	43	61	90	78	75
2	Horizontal	57	67	90	78	78
3	Square	57	72	93	89	83
4	Perpendicular	43	89	93	89	86
5	Parallel	29	72	97	78	79
6	Right angle	43	94	100	100	92
7	Cylindrical	57	78	100	100	89
8	Rectangular	43	94	97	100	90
9	Temperature	71	89	86	100	87
10	Volume	29	67	79	89	71

Item no.	Concept	Std 6,3 (n=7)	Std 8,2 (n=18)	Std 10 (n=29)	TC (n=9)	Combined (n=63)
11	Expand	71	100	93	100	94
12	Pressure	14	39	62	56	49
13	Condensation	29	61	86	78	71
14	Conduction	14	61	72	44	57
15	Radiation	0	39	62	33	44
16	Vacuum	43	61	97	78	78
17	Evaporation	57	83	100	100	90
18	Primary	14	72	79	89	71
19	Tertiary	0	39	52	33	40
20	Secondary	57	94	90	100	89
21	Revolution	14	89	86	78	78
22	Space	86	94	83	78	86
23	Resistance	43	50	83	78	68
24	Quality	0	39	24	22	25
25	Current	71	89	97	78	89
26	Maximum	43	72	93	100	83
27	Atmosphere	71	67	66	67	67
28	Compression	57	72	93	89	83
29	Absorb	57	94	93	89	89
30	Particle	29	94	100	100	90
31	Saturate	0	50	83	67	62
32	Surface	57	83	97	89	87
33	Heat	43	11	45	22	32
34	Heat transfer	57	72	69	56	67
35	Circulate	71	78	100	89	89
36	Balance	100	94	100	67	94
37	Rotation	71	94	93	67	87
38	Revolution	29	72	83	33	67
39	Gravity	86	94	97	89	94
40	Oxidation	57	83	86	78	81
41	System	29	72	93	78	78
42	Join	57	89	97	89	89
43	Weight	71	94	100	100	95
44	Heat exchange	43	33	66	44	51
45	Process	14	94	100	89	87
46	Flow rate	57	78	90	89	86
47	Automatically	86	89	100	100	95
48	Manually	71	83	100	78	89
49	Air	86	100	93	89	94
50	Chemical process	57	83	93	78	84

TABLE 11: PERCENTAGE CORRECT RESPONSES FOR SUBJECTS WITH AN AVERAGE EDUCATIONAL LEVEL OF STD 6,3 (n=7)

% correct	Concept	
0	radiation, tertiary, quality, saturate	(4)
11 - 20	pressure, conduction, primary, revolution, process	(5)
21 - 30	parallel, volume, condensation, particle, revolution, system	(6)
31 - 40		
41 - 50	vertical, perpendicular, right angle, rectangular, vacuum, resistance, maximum, heat exchange , heat	(9)
51 - 60	horizontal, square, cylindrical, evaporation, secondary, compression, absorb, surface, heat transfer, oxidation, join, flow rate, chemical process	(13)
61 - 70		
71 - 80	temperature, expand, current, atmosphere, circulate, rotation, weight, manually	(8)
81 - 90	space, gravity, automatically, air	(4)
91 - 100	balance	(1)

TABLE 12: PERCENTAGE CORRECT RESPONSES FOR SUBJECTS WITH AN AVERAGE EDUCATIONAL LEVEL OF STD 8,2 (n = 18)

% correct	Concept
11 - 20	heat (1)
21 - 30	
31 - 40	pressure, radiation, tertiary, quality, heat exchange (5)
41 - 50	resistance, saturate (2)
51 - 60	
61 - 70	vertical, horizontal, volume, condensation, conduction, vacuum, atmosphere (7)
71 - 80	square, parallel, cylindrical, primary, maximum, compression, heat transfer, circulate, revolution, system, flow rate (11)
81 - 90	perpendicular, temperature, evaporation, revolution, current, surface, oxidation, join, automatically, manually, chemical process (11)
91 - 100	right angle, rectangular, expand, secondary, space, absorb, particle, balance, rotation, gravity, weight, process, air (13)

TABLE 13: PERCENTAGE CORRECT RESPONSES FOR SUBJECTS WITH AN AVERAGE EDUCATIONAL LEVEL OF STD 10 (n=29)

% correct	Concept
21 - 30	quality (1)
31 - 40	
41 - 50	heat (1)
51 - 60	tertiary (1)
61 - 70	pressure, radiation, atmosphere, heat transfer, heat exchange (5)
71 - 80	volume, conduction, primary (3)
81 - 90	vertical, horizontal, temperature, condensation, secondary, revolution, space, resistance, saturate, revolution, oxidation, flow rate (12)
91 - 100	square, perpendicular, parallel, right angle, cylindrical, rectangular, expand, vacuum, evaporation, current, maximum, compression, absorb, particle, surface, circulate, balance, rotation, gravity, system, join, weight, process, automatically, manually, air, chemical process (27)

TABLE 14: PERCENTAGE CORRECT RESPONSES FOR COMBINED STD 8 TO 10 GROUP ($\bar{X}$ = STD 9,3) (n=47)

% correct	Concept
21 - 30	quality (1)
31 - 40	heat (1)
41 - 50	tertiary (1)
51 - 60	pressure, radiation, heat exchange (3)
61 - 70	conduction, resistance, atmosphere, saturate, heat transfer (5)
71 - 80	vertical, volume, condensation, primary, revolution (5)
81 - 90	horizontal, square, parallel, temperature, vacuum, revolution, space, maximum, compression, oxidation, system, flow rate, chemical process (13)
91 - 100	perpendicular, right angle, cylindrical, rectangular, expand, evaporation, secondary, current, absorb, particle, surface, circulate, balance, rotation, gravity, join, weight, process, automatically, manually, air (21)

TABLE 15: PERCENTAGE CORRECT RESPONSES FOR SUBJECTS WITH TEACHERS CERTIFICATES (TC) (n=9)

% correct	Concept	
21 - 30	quality, heat	(2)
31 - 40	radiation, tertiary, revolution	(3)
41 - 50	conduction, heat exchange	(2)
51 - 60	pressure, heat transfer	(2)
61 - 70	atmosphere, saturate, balance, rotation	(4)
71 - 80	vertical, horizontal, parallel, condensation, vacuum, revolution, space, resistance, current, oxidation, system, manually, chemical process	(13)
81 - 90	square, perpendicular, volume, primary, compression, absorb, surface, circulate, gravity, join, process, flow rate, air	(13)
91 - 100	right angle, cylindrical, rectangular, temperature, expand, evaporation, secondary, maximum, particle, weight, automatically	(11)

TABLE 16: PERCENTAGE CORRECT RESPONSES FOR GROUP AS A WHOLE (n=63)

% correct	Concept
21 - 30	quality (1)
31 - 40	tertiary, heat (2)
41 - 50	pressure, radiation (2)
51 - 60	conduction, heat exchange (2)
61 - 70	resistance, atmosphere, saturate, heat transfer, revolution (5)
71 - 80	vertical, horizontal, parallel, volume, condensation, vacuum, primary, revolution, system (9)
81 - 90	square, perpendicular, cylindrical, rectangular, temperature, evaporation, secondary, space, current, maximum, compression, absorb, particle, surface, circulate, rotation, oxidation, join, process, flow rate, manually, chemical process (22)
91 - 100	right angle, expand, balance, gravity, weight, automatically, air (7)