CHAPTER VI

LEARNING HIERARCHY

6.1 Introduction

Learning hierarchies are nested sets of tasks in which positive transfer from simpler to more complex task is expected. The 'simpler' tasks in a hierarchy are the components of more complex ones. Acquisition of a complex capability, then, is a matter of cumulation of capabilities through successive levels of complexity. Transfer occurs because of the inclusion of simpler tasks in the more complex. The hierarchy analysis has come into rather widespread use among instructional designers particularly in the field of [illegible] science and mathematics (White 1973a). For most part the analysis have have been of the kind Gagne (1962, 1968) originally described. Gagne's work on hierarchies of learning consists in the splitting up of a complex task into simpler ones and organizing them in a proper sequential hierarchical order for instructional purposes. A connection between any two elements in this is validly hierarchical if no learning can take place for a higher order skill without mastering the lower order skills. Instruction would begin, then, with the lower level capabilities to be mastered and proceed upward.

group is exposed to the special hierarchy based learning strategy while the control group has been put through no such special arrangement. Yet, both the groups were evaluated for their achievement through common assessment tools which were designed to test the possible hierarchy in their learning outcomes. This places the data in a unique comparative perspective. It helps us to test the hypothesis, whether, hierarchy in learning outcomes is essentially the fall out of a hierarchy based instructional strategy or it is a more predominant characteristic of the learning itself, independent of the method of instruction.

This chapter while reporting the study conducted by analysing the data obtained to see the existance and effects of hierarchy in learning, also reviews, the learning hierarchy studies based on Gagne's assumptions, in a historical perspective.

6.2 Studies in Learning Hierarchies

Learning hierarchy research began with a small preliminary study by Gagne in 1962, in which he attempted to teach seven children how to find formulas for sums of terms in number series. Gagne suggested that this skill could not be acquired unless the learners possessed certain pre-requisite skills which were identified by asking "What would the individual have to be able to do in order that he can attain successful performance on this task provided he is given only instruction?" (Gagne, 1962, p.358). The same question was then applied to each of the pre-requisite skills, thus identifying more skills; the process was continued until more basic skills were reached. In this way, Gagne derived a net work of elements which he called a learning hierarchy. He observed that none of the children acquired a skill without also acquiring all of the skills that were shown as subordinate to it in the hierarchy. This result suggested that if hierarchies were generally valid representations of the sequences in which the skills or elements of knowledge must be learned, they would be valuable tools for shaping more effective instruction for the acquisition of problem solving skills and knowledge in general.

In the three major investigations initially done by Gagne and his co-workers, Gagne and Paradise (1961) used a programmed book to teach 118 students, a hieararchy of 22 elements known then as "learning sets", which led to the element 'solving linear equations'. At the end of the instruction the samples were tested on achievement of the final element, on transfer of these skills to equations with unfamiliar letters and an achievement of twenty two subordinate elements. The result showed that the number of students who learned the higher elements without possessing the relevant subordinate ones were small. Gagne and Paradise (1961, p.9) suggested that these exceptions were due to errors in hierarchical connections and measurement. Also the time delay between learning and assessment may have contributed to the exceptions noticed.

Gagne, Mayor, Garstens, and Paradise (1962) wrote another hierarchy for mathematical subject matter. It had fourteen elements and a double peak. A learning programme was specially written and was given to 136 seventh grade pupils, who were tested on an achievement of the final two elements and twelve subordinate ones. There were fewer exceptions in this case than in the previous one by Gagne and Paradise (1961). Gagne and staff of the University of Maryland Mathematics Project (1965) conducted another major study using a hierarchy in mathematics and again only very few exceptions to the postulated hierarchy were observed.

Following Gagne's study many others got interested in the study of learning hierarchies. Kolb (1967-68) used the same method as Gagne and Paradise (1961) with a programme written specifically to teach the twentysix elements of his hierarchy. Kolb found that many students succeeded at tests of higher elements while failing to learn supposedly relevant lower ones. In the most extreme case 79 of the 128 students have exceptions to the postulated hierarchical connections. An explanation for these large number of exceptions could be found in Gagne's (1968) distinction between intellectual skills and verbalised knowledge elements which was not available to Kolb at the time of his study. The steps for which Kolb found largest numbers of exceptions usually involved verbalised knowledge elements.

Support for Gagne's comtention was provided by White (1971), who, in a learning hierarchy prepared for finding the velocities from position-time graphs, found that nearly all of the connections which involved a pair of intellectual skills were supported by his student performances, while all the connections leading to a verbalised knowledge element were not.

Oslen's (1968) hierarchy contained skills used in constructing and interpreting graphs. He attempted to validate his hierarchy by testing whether one element was more difficult than the other. Raven (1967) used the same method for his study of development of the concept of momentum. Okey (1968) tested several small hierarchies based on elementary physics concepts.

Resnick (1967) wrote several interesting hierarchies which had as their terminal elements classical Piagetian tasks such as conservation of quantity and measuring a line in standard units. Resnick and Wang (1969) attempted to validate two such hierarchies. However definite conclusion on the validity could not be drawn because of the unknown sequence in which the elements were acquired (White, 1973b).

Okey and Gagne (1970) examined the effect of learning of subordinate skills on learning of a superordinate skill by means of programmed unit on solubility product. The authors appropriately concluded that the significantly better performance of the group receiving additional instruction on failed subordinate skills supports the cumulative learning model as happens through learning hierarchy. More recently, Sedden (1974) found general chemistry knowledge to be the best predictor to understanding of the Kimball Change Cloud Model of chemical bonding, a result interpreted as supporting Gagne's hierarchical model. Gower, Daniels and Lloyd (1977) were concerned with identification of a hierarchy for the mole concept. A consistency ratio was used as the measure of hierarchical dependency. No firm conclusion with respect to the existence of either empirical or theoretical hierarchy emerged.

Trembath & White (1980) carried out an investigation to explore factors which might further improve the mastery learning strategy developed by Bloom (1968) and refined by Block and Anderson (1975). The results imply that improved performance of learners can be expected if validated learning hierarchies are used to sequence learning materials intended for teaching of intellectual skills. Evidence from this investigation suggests that almost all learners who can read reasonably well can meet a most stringent level of mastery achievement, even for a demonstrably difficult skill when working through a learning programme based on a hierarchy.

The best known and the most extensive attempt to apply Gagne's hierarchical model in science was "Science: A Process Approach" (SAPA, AASS, 1968) with its integrated net work of hundreds of skills. However, most studies under this involving the learning hierarchy model restricted the content to somewhat small numbers of skills. Indeed, Gagne (1973) no longer considers SAPA to be an ideal example of learning hierarchy.

Support for the learning hierarchy model varied from moderate to very strong. For this, Gagne suggests that there is great need for realising the difference between verbalised knowledge and intellectual skills. Verbalised knowledge is involved in, say, recall of a specific fact or the statement of a theorem etc., but intellectual skills deals with a whole class of tasks which include concept capability, problem solving capability etc. Most of those who found less support for the hierarchy, Gagne says, were involved in testing using elements which were most probably verbalised knowledge. Gagne went on to express his doubt about the validity of learning hierarchies for verbalized knowledge elements. "..... I am led to think that learning hierarchies are discriptions of the realationships of positive transfer among intellectual skills, but that they are not descriptions of how one acquires verbalized knowledge". (Gagne, 1968, p.5). White (1971) wrote a learning hierarchy that contained verbalised knowledge and intellectual skills and confirmed the point raised by Gagne. Gagne's hypothesis of learning, therefore is supported for intellectual skills. Much of the subject matter of mathematics and physical sciences is of this type, so learning hierarchy should be particularly valuable in those subjects. Intellectual skills appear to be more difficult to delineate in other subject areas compared to science and mathematics where it is very explicit.

As far as the generalizability of learning hierarchies is concerned, one important study by Linke (1975) needs our attention. Linke validated a hierarchy of graphical skills with seventh grade children attending high schools in the Melbourne suburban area. He also investigated the validity of the hierarchy for eighth grade children in two other Australian states, where different curricula were followed and for ninth grade Papuan children, of markedly different cultural background in the Port Moresby area. Linke found that the validated hierarchy had the same form for all these groups. Linke's hierarchy results imply that a learning hierarchy is valid for people of any age or background, a result which may greatly simplify problems of validating and applying hierarchies.

Hierarchies in Different Subject Areas

Most of the investigations carried out on learning hierarchies have been concerned with intellectual skills that would generally form part of mathematics or science curricula in schools. Gagne's hierarchies contained arithmetic, algebraic and geometric skills. White (1974c) and Linke (1973) were concerned with graphical skills in mathematics, physics and biology; Kolb (1967,1968) studied the effect of learning the skills in a mathematics hierarchy on achievement in science; and Merril's studies (Merril, 1965; Merril and Stolurow, 1966; Merril, Barton and Wood, 1970) was concerned with an imaginary science. It is significant that the review of hierarchy research by Walbesser and Eisenberg (1972) appeared in a report from science and mathematics devision of ERIC. Resnick's studies (Resnick, 1967; Resnick and Wang, 1969; Resnick, Siege, and Kresh, 1970) dealt with the investigation of basic skills which included counting and classification skills. It is apparent that the bulk of learning hierarchies studies are in science and mathematics. In subjects which consists largely of verbal information, such as history, there are many intellectual skills of the concept type, but rules are less common, and so hierarchies may be rarer and less useful than in mathematics or science. But one probably fruitful area is language skills especially grammar. Possibly, quite many other areas can also be identified. Learning hierarchy model has been and can still further be of great attraction and use to teachers and curriculum developers of any subject area. Only the degree of application may vary.

6.3 The Purpose of the Study

The purpose of this study was to investigate the application of the idea of learning hierarchies to an area of physics curriculum. Whichever way the hierachies are validated the investigation involves a sample drawn from a population. The population will, however, have circumscriptions. Typically it will be limited to children of one grade level from one school system in one city. It will contain children in a narrow age band, who have had similar educational experiences and who have similar cultural backgrounds. This, of course, is true of practically any study in educational research. However, it would be very useful to find that an educational idea is validated with a much wider population. Besides differences in populations, differences in the form of instruction, the context of instruction and the mode of instruction also should be taken into account while confirming the utility

(3) Does the existence hierarchy or otherwise in learning depend upon the type of sequencing of instructional inputs?

6.4 Method

One of the problems associated with the identification of validated learning hierarchies has been the absence of accepted statistical methods (White, 1973). Quite a few methods had been employed in the learning hierarchy studies in the past (White and Clark 1973, Dayton and McReady 1976, Airasion and Bart 1975). The analysis in these were based on the number of questions answered out of a selected few, based on each element to be mastered. The procedure in these types of testing was too complex and highly time consuming for any fruitful work to be done in a normal classroom setting without creating any administrative problems for the school concerned. Therefore, it is to be admitted that there is no fool proof or adequate method yet on hierarchical studies where each element is supposed to be subsumed by higher order ones which can be used in the normal classroom setting.

The method adopted by the investigator, involved the use of the necessary conditions to support the existence of a hierarchy i.e. Concept Score $\geqslant$ Rule Score $\geqslant$ Problem Score. This is done in the following respects :

(i) Descriptive analysis using mean and standard deviation based on the level-wise (concept, rule, problem) achievement on criterion tests.

(ii) Analysis of few individual cases.

(iii) Chi-square test analysis.

As mentioned earlier each criterion test was divided into three parts : Part-A: Concepts, Part-B: Rules and Part-C: Problems. Equal weightage was given to each section. Mean scores on each of these tests were analysed to see whether they fulfil the necessary condition $C \geqslant R \geqslant P$. A qualitative analysis was also done by taking the individual scores of six students (3 from group A and 3 from group B) to see whether their scoring in problem solving depends on the score in lower order capabilities in rules and concepts. The scores, level-wise, were analysed to group the sample into two: (i) those fulfills the necessary condition $C \geqslant R \geqslant P$ and (ii) those with all other variations i.e. $C > R < P$, $C < R < P$ or $C < R > P$. Chi-square was calculated on the scores of hierarchy group (N), i.e., the first group and Non-hierarchy group (NH) i.e., the second group, against equal probability.

6.5 Data Analysis and Discussion

The data required for hierarchy analysis, as mentioned earlier, was obtained through criterion tests in the experiment described in the previous chapter. Group A was exposed to the instructional strategy developed based on Gagne's conditions of learning, while group B, the control group, was not exposed to any such thing. The analysis is performed based on the scores at the concept level, rule level and problem solving level. The first part of this section is based on a level-wise analysis using tables 6.1, 6.2 and 6.3. The second part gives a qualitative analysis of scores on a few selected students (table 6.4). The third part of this section describes of chi-square analysis.

(a) Level-wise Analysis

The three levels which we considered for our study were concepts, rules and problem solving. The values of these were separately obtained for each criterion test. Table No.6.1 shows the mean and standard deviation values of concepts and rules on the criterion tests in respect of both group A and group B. A mentioned earlier criterion test IV was dropped from the analysis for want of

Table No.6.1 : Mean and S.D. - Group A & B
(Criterion Tests)

CONCEPTS - RULES

TESTS		GROUP - A				GROUP - A			
		Mean		S.D.		Mean		S.D.	
		C	R	C	R	C	R	C	R
Criterion Test	I	85.68	51.62	14.25	18.82	74.41	49.41	12.17	20.14
" "	II	83.51	57.84	11.90	19.05	62.94	33.24	15.63	19.51
" "	III	88.92	54.85	11.81	22.97	63.82	35.59	19.25	18.18
" "	IV	94.05	58.92	6.76	40.79	77.94	36.47	17.28	40.79
" "	VI	82.97	77.57	14.49	16.34	65.59	65.59	29.42	20.61
" "	VII	80.81	71.89	16.17	23.81	70.29	53.24	18.23	22.97
" "	VIII	82.97	66.49	21.67	20.30	77.06	65.59	22.56	23.41

C = Concepts

R = Rules (Principles)

sufficient data. The test No.IV was conducted only at the concept level. A close look at the group A scores reveals the capability achieved by the students at the concept level. The mean value varies between 80.81 and 94.05 a very high value, for concepts while it varies between 51.62 and 77.57 for rules. In all the cases we see that the concepts scores are higher than rule score which satisfy our necessary condition that $C \gg R$ for the establishment of hierarchy. The mean value, for the first test at the concept level, 85.68 shows the mastery reached by the students at this level which was fairly good. The average score on rules was 51.62 less than that of concept mean. This happens because as the test moves from concept to rules the complexity increases and as a consequence the difficulty level may also increase. This is also clear from the increased value of standard deviation value from 14.25 at the concept level to 18.82 at the rule level; showing larger variation. The second test also shows $C > R$ with mean values 83.51 and 57.84. The variation in score is comparable to that in the first test. The third test the concept mean has movedupto 88.92 with a lower value of 54.85 for rules. For the fifth test the concept mean reaches an altime high value of 94.05. The rule mean for the first 4 tests have remained almost the same in fifties. Fifth test score shows a very large variation at the rule level which may be due to the increased difficulty level of test items. The tests 6th, 7th and 8th also show the same trend with concept mean greater than rule mean. The group B values also shows a similar trend eventhough there was no hierarchy based input for them. The variation in the scoring pattern is also similar to that of group A. The value of mean score for test No.6 shows equal which still satisfy our necessary condition as C = R. Means 74.41 and 49.41 for concepts and rules for the first test shows a considerable difference between the two levels in achievement concepts and rules. More variation is noticed throughout in the case of rule achievement compared to concept achievement. In the 2nd test concepts gets a mean value of 62.94 while that for problems is only 33.24 a result similar to that of the first result. Third test result with mean values of 63.82 and 35.59 again shows the same pattern being followed. The mean score value for that IV shows the typical scoring pattern with values 77.94 for concepts and 36.47 for rules. The standard deviation values shows the pattern similar to that of group A. There is a sudden increase in the variation of scores for rules with S.D. value at 40.79 compared to the normal variation around 20. As said in the case of group A, this could have been created by the possible difficulties in the case of the test items in rule section. The result in the case of tests VII & VIII are also similar. We see as a whole that mean values of rules are less than those of concepts revealing a hierarchical relationship between concepts and rules.

Table No.6.2 is related to rules and problem solving. In all cases group A mean values for problem solving score were less than that of rules except in one case viz. test III where the value for 'problem solving' slightly exceeded the value for rules. The same difference is also noticed in case of test III in group B scores. This means that there may be some errors in the formulation of test items for problem solving. Tests V to VIII show higher mean values for rules. There seems to be more variation in problem solving scores compared to that of concepts or rules. As a whole the data shows the dependency of problem solving on rules. The higher mean score of rules over problem solving certainly shows the direction of dependency and the hierarchical relation.

Table No. 6.2 : Mean & S.D. of Criterion Tests - Group A & B

RULES - PROBLEM SOLVING

TESTS	GROUP - A				GROUP - B			
	Mean		S.D.		Mean		S.D.	
	R	P	R	P	R	P	R	P
Criterion Test I	51.62	47.57	18.82	25.41	49.41	28.24	20.14	20.07
" " II	57.84	57.03	19.05	30.3	33.24	17.06	19.51	25.73
" " III	54.86	57.84	22.97	24.40	35.59	55.59	18.18	21.03
" " V	58.92	57.03	40.79	29.67	36.47	32.35	40.79	30.10
" " VI	77.57	45.14	16.34	24.56	65.59	40.88	20.61	22.14
" " VII	71.89	47.30	23.81	34.14	53.24	35.29	22.97	38.29
" " VIII	66.49	63.24	20.30	24.83	65.59	40.00	23.41	21.00

The second part of table No.6.2 gives control group mean scores on rules and problems. Topic III means shows a set of means entirely different from other scores. The higher mean value 55.59 for problems compared to the lower value of 35.59 for rules is of the same pattern noticed the same topic in group A scores indicating the need for possible correction to the test items employed. All other scores indicate higher mean score for rules and much lower mean score for problems. Though they are being taught without the material with hierarchical design, the score shows hierarchical relation, indicating hierarchy among these elements in the subject is independent of the type of input.

From the earlier discussion which was test-wise, based on the criterion test scores we can conclude, without any hesitation, the existence of hierarchical relation. This is further supported by the scores in table No.6.3 on combined criterion test values. The values show clearly that as the child proceeds from concept to problem the achievement score decreases. One interesting aspect in this table is that as the achievement scores goes on decreasing from lower level skill to higher order skills the variation in scoring pattern increases. This is due

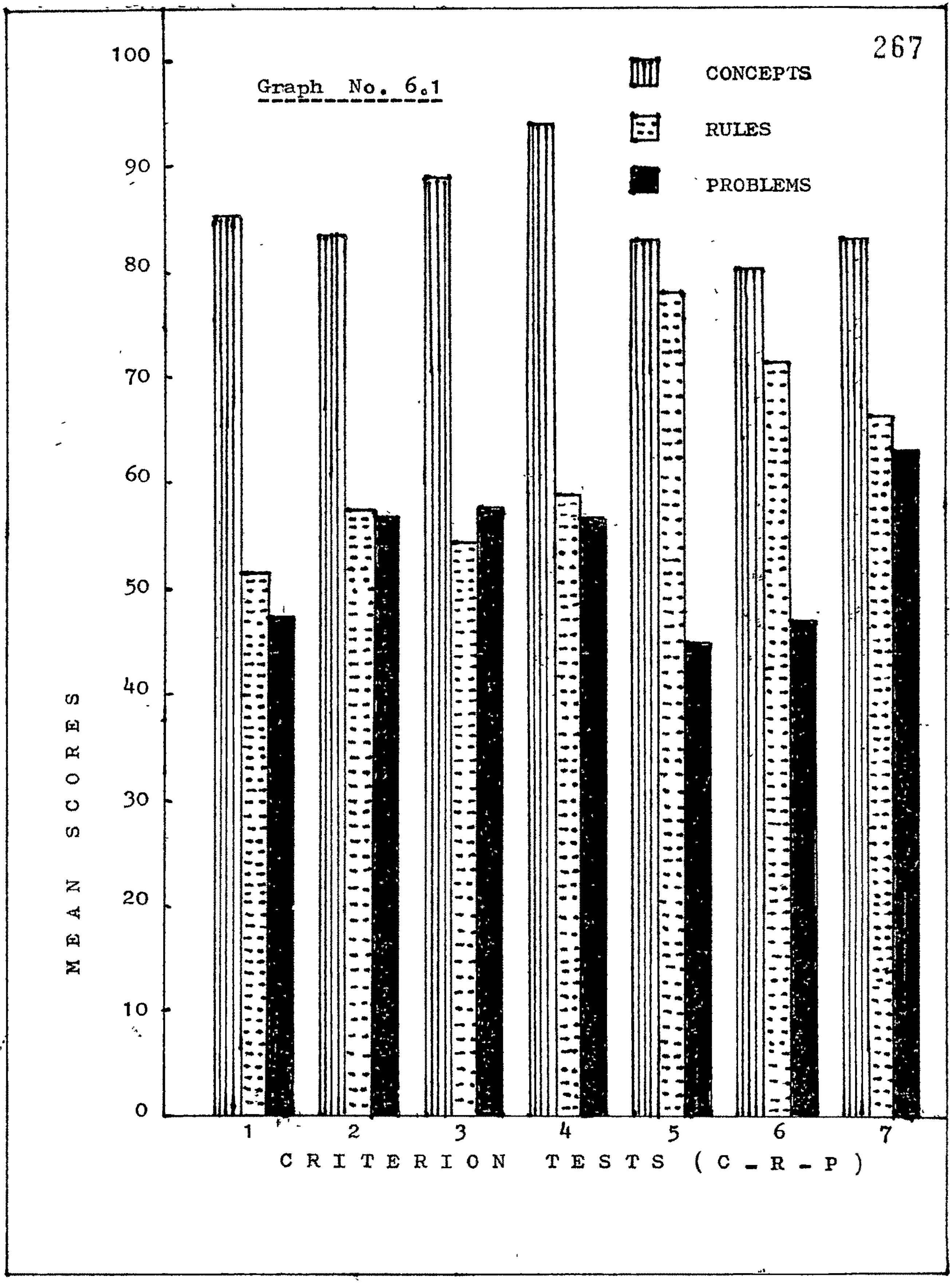
Table No. 6.3 : Mean and Standard Deviation Values on Combined Criterion Test Scores

	GROUP - A		GROUP - B	
	Mean Score	S.D.	Mean Score	S.D.
Concepts	84.51	9.13	68.74	8.96
Rules	62.58	14.57	48.33	12.19
Problems	52.82	19.31	35.71	16.33

to the fact that the complexity in learning increases as one goes to higher order skills. This variation in scoring pattern as well as standard deviation substantiate the fact that the hierarchy aspect does not depend on the mode of instruction but is an independent factor important to learning.

After having analysed all these means scores tabulated, if we look at the actual scores certain other aspects come to light. In the first criterion test 7 students scored more than 75% marks in problems. Any score above 75% was chosen, as this was considered as outstanding performance in earlier discussions. All these five students scored above 75% at the concept level also. But at the rule level 2 students scored less than 50%, two 60% each and rest 3 above 75%. In the 2nd test out of the 11 who got above 75% in problems 10 scored above 75% in concepts with one getting 70% and 9 of them scored above 75% in rules with 2 of them getting less than 50%. In the third test out of the five getting above 75% in problem solving all of them gets [illegible] above 75% in concepts, three of them above 75% in rules and other two 60 & 70 respectively. In the case 5th test out of the nine students getting 75% and above in problems all nine get 75% and above in concepts, 7 gets more than 75% in rules with two less than 50%. Also in this test 6 students gets 100% marks in all three; concepts, rules and problems and two cases of 90-100-100 and 100-90-100 each. In the case of 6th test, 5 students gets above 75% in all the three, concepts, rules and problems. In the case of test seven, out of the nine getting above 75% in problems, 6 gets above 75% in concept and rest between 50% and 75%; 6 gets above 75% in rules and the other three between 60% and 70%. In the case of test eight, 12 students scores above 75% in problems, out of which all the 12 get above 75% in concepts also but only 9 scores above 75% in rules, the rest then between 50% and 75%. On the whole we see that those who are getting high scores in problem solving are also getting the similar scores in rules and concepts. Exceptions are very few to think of any discord on the pre-requisite conditions. In the case of group B, the control group, in criterion test scores out of 24 scores above 75% in problems, 19 of them fulfills same criteria in concepts and 12 of them in rules. Group B scores shows more variation through the exceptions are not too many. All these scores clearly indicate the hierarchy relationship in the performances.

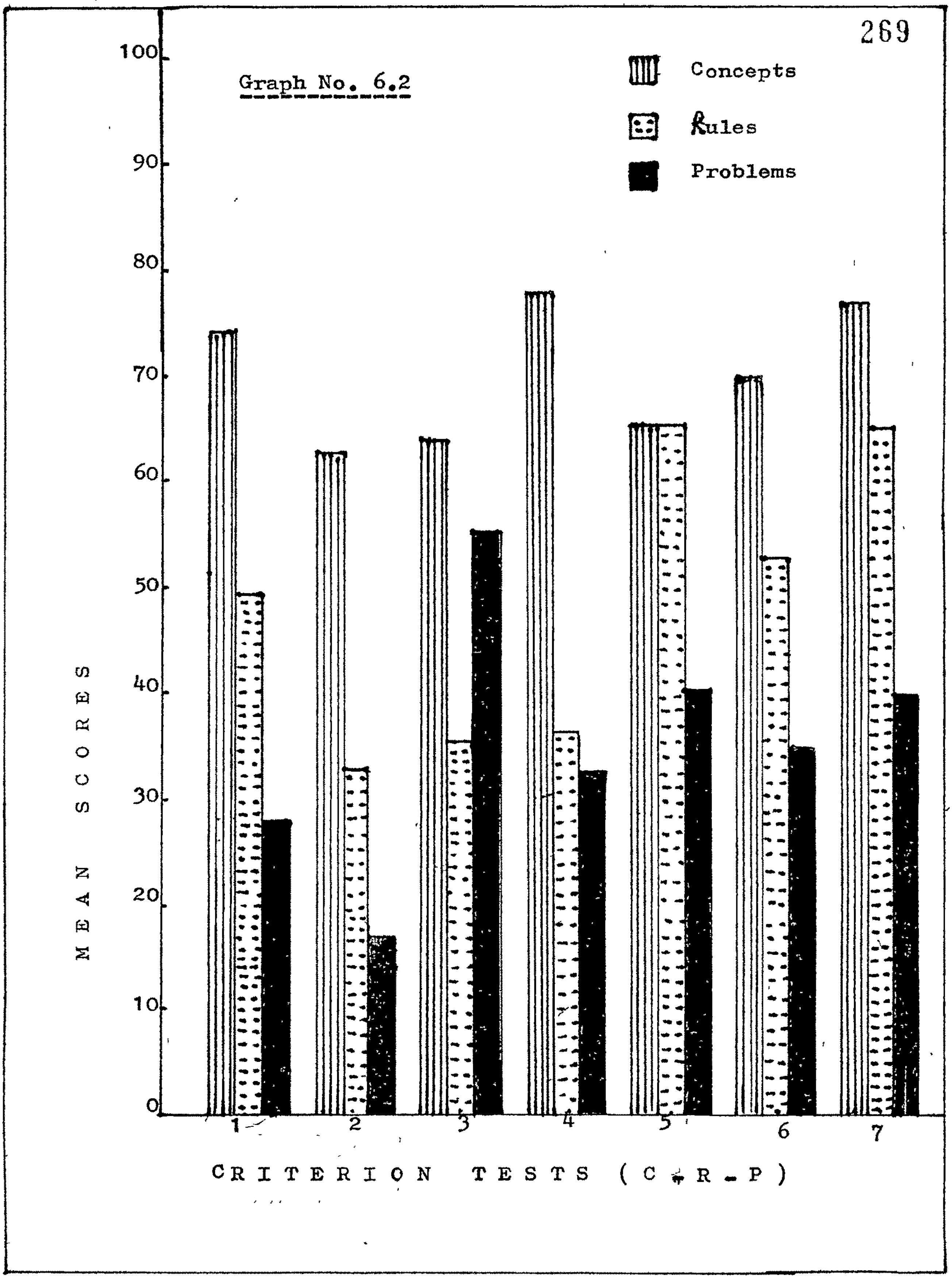
The Graph No.6.1 shows a representation of criterion test scores in respect of concepts rules and



Graph No. 6.1
CONCEPTS
RULES
PROBLEMS
MEAN SCORES
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
CRITERION TESTS (C - R - P)

problem solving against the mean scores in percentage in the case of group A. It is very clear that in all cases the score for the concepts are very high. In test No.6 and 7, there is a marked difference between rules and problem solving. In most cases, the value for rules and problem are very near. This may be because the test item at problems level may be very near to the rule level. The bar-graphs show beyond doubt that the values satisfy the minimum condition required for establishing the hierarchy $C \geqslant R \geqslant P$ except in case of the test No.3 where it is seen that $P > R$. This may be due to some aspects in the test items itself as this is noticed in group B also.

Graph No.6.2 shows the mean value distribution for group B. In fact it is in group B we find the real test for hierarchy as they were not oriented towards the hierarchy idea. As was expected the histogram shows very clear cut relation for $C > R > P$ in 5 cases. In one case, i.e., the 3rd test shows a result $C > R < P$ and 5th test $C = R > P$. Thus, except for the relation between R and P in 3rd test all other cases show $C \geqslant R \geqslant P$. The difference between R and P is more prominent in group B scores than in group A scores. Therefore these values establishes the hierarchy relationship beyond doubt and


Graph No. 6.2
Concepts
Rules
Problems
100
90
80
70
60
50
40
30
20
10
0
MEAN SCORES
1
2
3
4
5
6
7
CRITERION TESTS (C-R-P)

the control group scores proves that this relationship has nothing to do with the mode of instruction.

(b) Analysis of Individual Cases

If we just analyse a topic, say No.5, on conservation of momentum, out of ten, nine concepts were dealt as reviewing concepts from the previous topics. They included: (i) Scalar quantities, (ii) Vector quantities, (iii) Time, (iv) Displacement, (v) Velocity, all five from the first topic, (vi) Acceleration from second topic, (vii) Mass, (viii) Momentum, (ix) Force from topic 3. Therefore, a students scoring in topic 5 will definitely depend upon his mastery over the pre-requisite concepts and hence can be related to his score in the first, second and third topic. If we look at the scoring pattern as given in table No.6.4. We see that the student Anirban who is scoring 100 in the fifth test for problem solving scores 100, 100 and 90 for concepts in the first three tests which actually speaks of his mastery over those concepts. The student Punam who is getting ninety in problem solving for the fifth test scores has been scoring consistently with 100 each in the first three tests for concepts. Another student Rupal who scores

Table No. 6.4 : Individual Test Scores

Group-wise Name of the Respondents	P_5	Concept Scores in Various Criterion Tests				R_5
		C_1	C_2	C_3	C_5	
GROUP-A :						
Anirban Choudhari	100	100	100	90	100	100
Punam Kunwar	90	100	100	100	100	90
Rupal Sastri	40	60	80	70	90	70
GROUP-B :						
Vikas Chokshi	90	90	70	90	100	40
Jayesh Patel	60	80	90	50	90	100
Kalpesh Patel	20	70	40	70	90	20

less marks in fifth test for problem solving equal to 40 marks, scores only 60, 80 and 70 marks respectively in his first three tests for concepts which directly correlates our assumption about the necessity of pre-requisite learning. All the three cases discussed above were from experimental group. If we take some cases from control group; for instance student Vikas who scores 90 in problem solving for the fifth test scores 90, 70, and 90 for the first three tests respectively. Another student Jayesh who scores only sixty in problem solving for the fifth test gets a score of 80, 90 and fifty for the first three test respectively for concepts. A third student Kalpesh who scores only 20 in problem solving in the fifth test scores 70, 40 and 70 in the first three tests for concepts. The above analysis for a few students shows clearly how problem solving capability depends on their concept capability. Science and especially physics being a highly hierarchically organised subject, mastery over the lower order capabilities becomes extremely important for better achievement at the higher order capabilities.

(c) Chi-square Test Analysis

A close look at the chi-square value given in table 6.5 and 6.6 for experimental group and control group

Table No. 6.5 : Group A - Experimental Group

Criterion Tests		fo	fe	fo-fe	$(fo-fe)^2$	X^2	P
Test 1	H	24	18.5	5.5	30.25	1.635	0.20
	NH	13	18.5	-5.5	30.25		
Test 2	H	20	18.5	1.5	2.25	0.1216	0.70
	NH	17	18.5	-1.5	2.25		
Test 3	H	16	18.5	2.5	6.25	0.3378	0.50
	NH	21	18.5	-2.5	6.25		
Test 4	H	20	18.5	1.5	2.25	0.1216	0.70
	NH	17	18.5	-1.5	2.25		
Test 5	H	27	18.5	8.5	72.25	3.9054	0.05
	NH	10	18.5	-8.5	72.25		
Test 6	H	19	18.5	0.5	0.25	0.0135	0.90
	NH	18	18.5	-0.5	0.25		
Test 7	H	23	18.5	4.5	20.25	1.0945	0.30
	NH	14	18.5	-4.5	20.25		
Combined	H	29	18.5	10.5	110.25	5.9594	0.02
Test Score	NH	8	18.5	-10.5	110.25		

respectively we see the validity of the learning hierarchies. The necessary condition for the existence of a hierarchy is taken as the scores on concepts must be greater than or equal to rules and the scores on rules must be greater or equal to that of problem solving ($C \geqslant R \geqslant P$). This is taken under the group H showing hierarchy. There are three other possibilities namely, $C > R < P$, $C < R > P$ and $C < R < P$; all of them being clubbed under non-hierarchy (NH). The X^2 value is calculated against equal probability between the two. In table 6.5, we see that value for test 5 shows considerable divergence towards the hierarchy side which is significant at .05 level. Though the divergence in other cases is not very much the necessary condition is met in all cases as the value of H is greater than NH (H > NH). The seven test scores combined values shows that while 29 cases are in favour of hierarchy only 8 are against it (H >> NH). The chi-square value of 5.9594 is highly significant at .02 level, showing greater divergence towards the existence of hierarchy.

Table No.6.6 shows the results of test No.1 chi-square value of 3.765 is significant at .05 level showing a divergence towards hierarchy (H > NH). Test No.2 values shows a chi-square value of 4.765 which is significant at .02 level (H >> NH). But test No.3

Table 6.6 : Group B - Control Group

Criterion Tests		fo	fe	fo-fe	$(fo-fe)^2$	X^2	P
Test 1	H	25	17	8	64	3.765	0.05
	NH	9	17	-8	64		
Test 2	H	26	17	9	81	4.765	0.02
	NH	8	17	-9	81		
Test 3	H	8	17	-9.5	90.25	5.3088	0.02
	NH	26	17	+9.5	90.25		
Test 4	H	15	17	-2	4	0.2352	0.70
	NH	19	17	2	4		
Test 5	H	22	17	5	25	1.4705	0.20
	NH	12	17	-5	25		
Test 6	H	21	17	4	16	0.9412	0.30
	NH	13	17	-4	16		
Test 7	H	24	17	7	49	2.8823	0.10
	NH	10	17	-7	49		
Combined Test Score	H	28	17	11	121	7.1176	0.01
	NH	6	17	-11	121		

(i) Learning takes place hierarchically between concepts, rules and problem solving.

(ii) Problem solving at highest apex is followed by rules, with concepts coming at the bottom of the learning hierarchy.

(iii) The performance at the problem solving level depends on the rule capability and concept capability.

(iv) The performance at the rule level depends on the mastery at the concept level.

(v) The pre-requisite relationship between concepts, rules and problem solving as enunciated by Gagne holds good in the learning of physics.

(vi) The hierarchy relationship exhibited in the learning of concepts, rules and problem solving does not depend upon the type of sequencing followed in the instructional strategy.

The findings mentioned above, in fact give strong support to the 'learning hierarchy' condition, put forward by Gagne, in an altogether different situation with a different population.

There is thus good reason to believe that learning hierarchies as suggested by Gagne should form an effective tool leading to better learning. Because the development and validation of a learning hierarchy enforce precise behavioural definition of the terminal skill and produce a detailed description of its prerequisite skills, it is simple, for instruction based on a hierarchy to meet the requirements in school learning (Trembath & White, 1980). A hierarchy makes it relatively easy to meet the requirements of sufficient time too, because it contains no irrelevant skills and because the sequence of instruction is clear, thus preventing loss of time that could otherwise occur while students batter away tasks for which they lack essential pre-requisites. Students should be able to understand the instruction based on a hierarchy because at every step it builds on what they can already do and moves them on a small step further.