Chapter 3

Some Educationally Relevant Studies of Learning

The salient facts about learning, reported in the previous monograph, are as follows: (1) If a condition of *understanding* (evidenced by an explanation and a derivation of each topic addressed) is secured during the learning process then the concepts learned are stable and reliably retained. (2) Either of the expedients (teachback or the CASTE operating system) employed to exteriorise normally concealed cognitive processes as stretches of dialogue in a strict conversation also guarantee that any topic learned is understood. Moreover, these arrangements promote understanding. (3) Students may learn on their own account, adopting an autonomously generated learning strategy. Alternatively, their learning may be guided by a teaching strategy imposed by an instructor or a mechanism. (4) In either case, a student has certain natural learning strategies. These may be used or may be dominated by a teaching strategy. The natural learning strategies belong to mutually exclusive classes named holist and serialist, as do teaching strategies. (5) If a teaching strategy and a learning strategy are *mismatched* (belonging to exclusive classes), learning and retention are impaired; understanding is difficult to achieve, or even unachievable. (6) Conversely, a matched situation enhances learning and retention.

The main conclusions are summarised in Table 3.1. The differences between matched and mismatched learning, reflected in these gross figures, are more poignantly exhibited by specific differences in the tutorial dialogue, the form of explanations and derivations.

This chapter is concerned with recent findings, and it is expedient to start the discussion from a less specialised and theoretically committed point of view. The cognitive process which goes on in a conversation has certain uncontentious characteristics;

TABLE 3.1

Differences Between Understanding/Not Understanding and Matched/Mismatched Learning: (I) Detailed Data (II) Gross Data from Study Using Different Students *.

Student Number	Clobbit Task (free learning) Test Scores		Student Classified as Serialist (S) or Holist (H)	Gandlemuller Task (Programmed text: either Serialist type or Holist type)	
	1st session (max. 30)	2 session (max. 30)		Program type	Test score (max. 30)
TB 1	13	30	S	H	9
TB 2	25	27	H	S	21
3	25	17	S	S	29
TB 4	10	28	S	H	7
5	27	23	H	H	30
6	15	5	S	H	9
TB 7	27	30	H	H	30
8	27	18	S	S	28
TB 9	28	30	H	H	30
10	17	13	S	S	30
11	23	19	H	S	19
TB 12	18	30	S	H	9
13	21	25	H	H	30
14	26	17	H	S	16
TB 15	21	28	H	S	20
16	22	17	S	S	29

* Students classified as holist/serialist on Clobbits task. Difference between 1st sessions/2nd session shows effect of teachback or simulated teachback (teachback test scores > simulated test scores significant 0.01 > p). Same students later learned from matched/mismatched programmed text about Gandlemuller taxonomy (similar in form but not in content to Clobbits). Subsequent retention test on Gandlemuller material shows matched scores > mismatched scores difference, significant at 0.001 > p. All comparisons use Mann—Whitney U-Test.

TABLE 3.1 (continued)

	Number	Mean % Test	S.D.
Matched	8	61.0	4.8
Mismatched	8	31.5	6.1
Any Understanding Conversational	10	96.0	5.6

Difference Matched > Mismatched significant at $0.001 > p$; difference Conversational > Matched significant at $0.001 > p$; Experiment used CASTE as operating system. (In part from Pask and Scott, 1972.)

nearly all theoretical formulations point them out, using different terminology. The characteristics of immediate concern are *embedding* (a neologism) and *style*.

1. EMBEDDING AND FIXITY

Embedding is an omnibus name for the conservative aspects of cognition. Not only concepts that are officially learned, but peripheral and possibly extraneous concepts become entrenched in a student's repertoire due to ubiquitous trapping and entrainment phenomena. Amongst the peripheral concepts that become entrenched is the *style* of learning about the officially relevant concepts. Regarding these "official" components as the "figures" in a psychological test, *style* is the "ground" against which the "figures" are displayed.

For Piaget (1921 to 1968) and his school, for example, the embedding operations are the general cycle of accommodation and assimilation subsumed by adaptive transformation and modulated by group development, *decalage* and the like. For Bartlett (1932) embedding is the conservation and invariance of schemata. Harlow (1959), at quite a different level, invokes mechanisms related to learning set; Helson (1964) an adaptation level; and the information-processing psychologists an irreversible component — for example, transfer from short-term to long-term storage (Atkinson and Shiffrin 1967) or distributed retention (Simon and Feigenbaum 1964). Our own theory predicts embedding as a consequence of executing the procedures (or compiled programs) called concepts and memories. These theories and a legion of others differ, with respect to embedding, chiefly in the form of wording employed.

If it happens that exclusion principles can be formulated so that one class of concepts is incompatible with another class of concepts, at least in the sense that members of these classes cannot be conjointly assimilated into a cognitive repertoire, then it is possible to strengthen embedding, and to speak of fixity. Again, all the theories do so. Perhaps the most general expression for incompatibility is *interference*, as this term is used by the eclectic information-processing psychologies, notably, Broadbent (1963, 1971), Entwistle (1975), and Welford (1968). Combining interference with embedding leads to the prediction of fixed states, either deep rooted concepts or deep rooted habits of searching for an integrating concept. Festinger's (1956) "Cognitive Dissonance" is a special case of fixity observed in such contexts as adherence to social beliefs (the original study) or hypotheses leading to a decision, for example, to purchase a product. "Cognitive Dissonance" is a specific mechanism for fixing concepts. Under these circumstances, whoever exhibits the fixity will reject or pervert to affirmative form evidence denying the accepted belief or hypothesis. In the present theory, "cognitive fixity" is employed as a noncommittal name for the result of processes that may be identical with Festinger's "dissonance" or which depend upon more general interference effects. The phenomenon of fixity is so well and widely evidenced that it counts as a basic fact of cognitive psychology.

We return to the question of fixity very soon, but before we do, some exclusion principles will be stipulated.

2. STYLE OF LEARNING

Style is the other salient characteristic of cognition. Since the previous monograph was written, several recent studies vouch for the reality of distinct and idiosyncratic learning styles.

For example, there is a body of work due to Daniel (1975), Dirkzwager (1974), Beishuizen (1974), and their colleagues on style in logical problem solving; by Klix (1973) on concept acquisition; by Strubb and Levitt (1974) on decision style; by Hankins (1974) on styles exhibited by engineering design students. Also, Landa's (1971) major work on logic and language learning has appeared in an English translation, edited by Kopstein, and apart from demonstrating the value of concepts that delineate rules, the protocol data clearly exhibit distinct (and often ineffective) indigenous styles. Mulling over the last few issues of *Instructional Science*, about one fifth of the papers are devoted to this topic, for example, Bree (1974) or Allen (1974); and about half of the *Structural Learning Proceedings* (Scandura, Ed. 1974).

Serious quantification of style is presaged and to some extent anticipated in Newell and Simon's (1972) account of thinking. But the notion of style (in contrast to its empirical exhibition) goes back to antiquity; see, for example, Yates (1966) scholarly account of the memorial and combinatory systems employed by the ancients, hy the mediaeval rhetoric schools, and others. Moreover, differences in style are reliably detectable outside the laboratory, most dramatically perhaps in the way people explore, learn about, and image their environment (Lynch 1960; Glanville 1975). There is little need to labour an obvious point; style is one of the commonest psychological observables; it has always been recognised by tutors, priests and actors; it is nowadays a respectable topic for overt discussion.

The conversational situations we employ reveal quite definite learning styles, several of which were described in the previous monograph. There, we mainly stressed two styles which are exhibited in a strict conversation as classes of learning strategy, holist and serialist. Shortly, it will be appropriate to recall and buttress the holist/serialist distinction, but before doing so, it is worth considering the styles manifest under less rigidly controlled conditions, in conversations maintained by "Free Learning" and "Teachback" for example (Chapter 1 and the previous monograph).

2.1. Comprehension Learning and Operation Learning

When a complex subject matter is learned by a student (for example, statistics, the menstrual cycle, various taxonomies) and when pains are taken to exteriorise his mental activities, it is possible to distinguish between comprehension learning and operation learning as dominant learning styles. The distinction is clearcut but not dichotomous. The styles are as follows.

Comprehension learners pick up an overall picture of the subject matter; for example, in a taxonomy the number of classes, the type and number of items in a class, redundancies in the taxonomic scheme, relations between the distinguished classes, a clear picture of where information about items can be discovered. These learners may or (significantly) may not be able to perform the operations required to use the subject matter information (here, to classify specimens). Often enough, comprehension of a layout or framework exists in the absence of rules or operational meaning and perhaps in ignorance of details that have to be filled in if the taxonomy (or whatever) is to be used in practice.

Conversely, operation learners pick up rules, methods and details but are often unaware of *how* they fit together, still less of *why they do* fit together. Typically, operation learners have at most a sparse mental picture of the material. Their recall of the way they originally learned (insofar as they learned at all) is guided by arbitrary numbering schemes or accidental features of the tutorial information frames.

2.1.1. Multi Purpose Experiments

A series of experiments (called the "multi purpose" experiments for reference) were carried out to investigate: (a) Means of determining style and their reliability, (b) the effect of securing or not securing understanding of each topic (by comparing effective teachback with simulated "ineffective" teachback, (c) the stability of a style-determined learning strategy over different subject matters, and (d) the influence of a matched as against a mismatched mode of tuition (teaching strategies either matched to a student or mismatched are built into programmed instruction materials). The subject matters used for learning and for style assignment were the two taxonomies (Gandlemuller and Clobbit) of the earlier studies, (Pask and Scott 1972), two biological subjects "The Operon" and "The Menstrual Cycle", and an inductive inference task.

The experimental design is shown in Fig. 3.1. The 62 students were from Kingston and Chiswick Polytechnics. Two batches were processed. Batch 1 (32 students) was exposed to the "Clobbit" taxonomy free learning task and each student was classified as a holist or serialist. At approximately two week intervals, subjects returned first for exposure to the "Gandlemuller" taxonomy task in a matched or mismatched condition, and second, for exposure to the operon cycle task in a matched or mismatched condition. They returned later for a final session of retention tests and teachbacks.

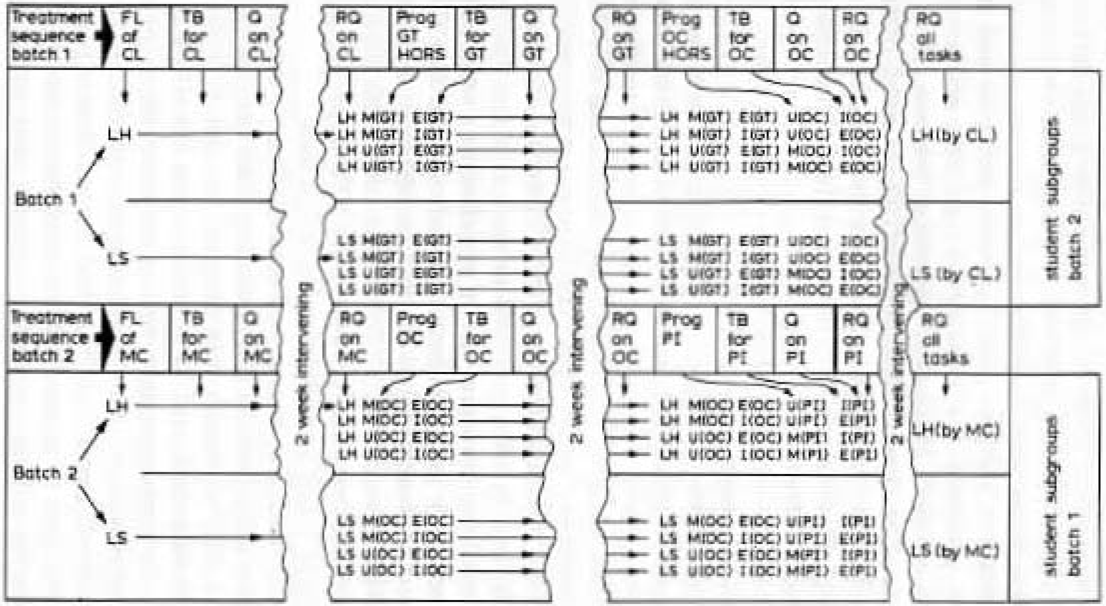

Fig. 3.1. Experimental design securing a balanced combination of matched (M) and mismatched (U) instruction and of effective (E) and ineffective (I) teachback (TB), for students classified as like holist (LH) or like serialist (LS) after free learning (FL), different initial subject matters (the Clobbits taxonomy CL and a menstrual cycle MC); other abbreviations are GT for Gandlemuller taxonomy, OC for operon cycle and PI for probabilistic inference. Q means "Questions Test" (including explanatory questions) and RQ is test questionnaire for long term recall.

TABLE 3.2

Summary of Data From Free Learning Session *

Student Group		Frequency of Intention types						Mean No. of Cards/Cluster	Mean Values of Uncertainty (H), Correct Belief (Θ), Look Ahead Uncertainty (H*), and Look Ahead Correct Belief (Θ*)			
		I	II	III	IV	V	VI		H	Θ	H*	Θ*
Batch 1 Operation Learners (n = 18) "Like Serialist"	Means	1.6	2.8	9.3	3.5	2.2	0.2	1.74	1.29	0.38	0.71	0.06
	SDs	1.7	1.9	5.3	1.9	2.5	0.03	0.36	0.80	0.31	0.87	0.28
Batch 1 Comprehension Learners (n = 14) "Like Holist"	Means	1.2	1.4	3.9	7.9	3.8	3.7	2.95	1.19	−0.05	1.32	0.28
	SDs	0.5	0.8	3.4	1.8	1.1	0.42	0.42	0.60	0.40	0.42	0.66
Batch 2 Operation Learners (n = 17) "Like Serialist"	Means	1.7	2.4	8.6	1.4	1.9	0.3	1.72	1.09	0.37	0.43	0.36
	SDs	1.0	1.3	1.9	1.0	1.5	0.5	0.30	0.68	0.21	6.47	0.32
Batch 2 Comprehension Learners (n = 13) "Like Holist"	Means	1.8	2.6	2.8	8.6	2.0	3.6	2.98	1.34	0.30	1.76	0.38
	SDs	1.0	1.2	1.7	2.0	0.9	1.0	0.36	0.89	0.26	0.64	0.32

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Statistical summary:

1. Frequency of intention classes IV and VI: comprehension learners > operation learners ($p < 0.001$).
2. Mean no. of cards/cluster: comprehension learners > operation learners ($p < 0.001$).
3. Operation learners have significantly higher means for θ ($p < 0.01$).
4. Comprehension learners provided values for H* and θ* on significantly more occasions ($p < 0.01$). (All comparisons by Mann-Whitney U-Test.)

Key for intention types:

I = exploratory perusal of cards
II = general search for information
III = looking for a particular piece of information
IV = looking for several pieces of information
V = testing a single predicate hypothesis
VI = testing a multi predicate hypothesis

TABLE 3.3

Content Analysis of Teachback Protocols

Student Group	Program Type	Subgroup Matched/ Mismatched		Classification of Statements 1	2	3	4	5	6	7
Batch 1 Operation Learners (n = 18) "Like Serialist"	Gandlemuller	matched (n = 9)	Means	1.5/0.5	0.2	0.8	0.3	0	0	34
			SDs	1.0/0.5	0.5	0.7	0.6	0	0	3.8
		mismatched (n = 9)	Means	1.0/0.1	0.2	0.3	0.8	7.0	1.5	30
			SDs	0.5/0.3	0.5	0.6	0.7	3.6	0.9	4.2
	Operon	matched (n = 9)	Means	0.9/0.2	0.2	0.5	0.2	0	0	35
			SDs	0.4/0.5	0.5	0.4	0.5	0	0	3.6
		mismatched (n = 9)	Means	1.5/0.5	0.2	0.5	0.2	8	2.2	32
			SDs	1.0/0.5	0.5	0.4	0.5	2.6	2.4	5.1
Batch 1 Comprehension Learners (n = 14) "Like Holist"	Gandlemuller	matched (n = 7)	Means	0.5/0.3	2.3	6.0	5.0	4.5	4.0	49
			SDs	0.5/0.4	1.9	4.2	4.0	4.2	3.8	14
		mismatched (n = 7)	Means	0.8/0.4	3.0	3.7	3.8	4.4	1.1	38
			SDs	0.1/0.3	2.6	1.8	2.2	2.6	2.4	6.3
	Operon	matched (n = 7)	Means	0.4/0.3	1.9	8.1	5.7	2.7	12	48
			SDs	0.5/0.4	2.2	3.6	2.8	3.3	9	10
		mismatched (n = 7)	Means	1.0/0	0.4	4.5	0.6	6.1	0.2	36
			SDs	0.5/0	0.5	2.4	0.5	3.1	0.4	5.0
Batch 2 Operation Learners (n = 17) "Like Serialist"	Operon	matched (n = 9)	Means	0.5/0.3	0.1	0.1	0.1	0	0	34
			SDs	0.3/0.3	0.1	0.1	0.1	0	0	4.5
		mismatched (n = 8)	Means	0.8/0.1	0.5	0.5	0.2	7.2	2.2	28
			SDs	0.7/0.1	0.7	0.7	0.1	2.4	1.8	3.6

	Probabilistic Inference	matched (n = 8)	Means	0.3/0.2	6.3	6.1	0.4	0	0	32
			SDs	0.1/0.1	0.1	0.1	0.2	0	0	3.4
		mismatched (n = 9)	Means	1.3/0.2	0.2	0.5	0	9.1	2.1	33
			SDs	1.1/0.1	0.1	0.2	0	2.6	1.6	5.4
Batch 2 Comprehension Learners (n = 13) "Like Holist"	Operon	matched (n = 7)	Means	0.1/0.1	2.6	6.1	8.0	6.3	5.3	52
			SDs	0.1/0.1	1.0	1.9	2.0	2.0	1.8	12
		mismatched (n = 6)	Means	0.5/0.2	3.5	3.2	2.5	4.0	0.3	40
			SDs	0.1/0.1	1.2	0.9	0.7	1.4	0.1	3.8
	Probabilistic inference	matched (n = 6)	Means	0.2/0	1.9	7.1	4.5	0.6	6.1	61
			SDs	0.1/0	0.4	1.5	1.0	0.2	2.0	13
		mismatched (n = 7)	Means	0.7/0.1	0.9	4.7	0.2	5.5	1.7	34
			SDs	0.2/0.1	0.2	1.6	0.1	2.8	1.8	3.1

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Key:
1 = falsehoods/corrected falsehoods
2 = inventions
3 = statements of information to come or delivered
4 = statements deduced
5 = irrelevant
6 = redundant
7 = total no. of statements (excludes interjections, repetitions and corrections)

Statistical Summary:
1. Comprehension learners type 2 statements > operation learners type 2 statements. ($p < 0.001$)
2. Comprehension learners type 3 statements > operation learners type 3 statements. ($p < 0.001$)
3. Comprehension learners type 4 statements > operation learners type 4 statements. ($p < 0.001$)
4. Mismatched operation learners type 5 and 6 statements > matched operation learners type 5 and 6 statements. ($p < 0.001$)
5. Mismatched students uncorrected falsehoods > matched students uncorrected falsehoods. ($p < 0.001$) (All comparisons by Mann-Whitney U-Test.)

Students given ineffective teachback on Clobbits were given effective teachback on Gandlemullers and ineffective teachback on the operon cycle. Students given effective teachback on Clobbits were given ineffective teachback on Gandlemullers, and effective teachback on the operon cycle. At each stage, half the students assigned to effective teachback had been classified as holists, and of those, half were in the matched condition. Retention tests were given and teachback protocols elicited for all tasks completed on earlier sessions, each time a student returned for further sessions.

Batch 2 (30 subjects) was treated similarly, but for them the free learning task was the menstrual cycle and the two programmed text tasks were the operon cycle and probabilistic inference. The mechanised version of the menstrual cycle task was introduced into the design during the latter part of the project; 18 of the Batch 2 students were classified as holist or serialist on the basis of their performance on the mechanised task.

2.1.2. Main Results

Predicted style assignment is based on the indices of Table 3.2. The most reliable quasi objective method of assignment depends upon the intentions that students expressed (by edict) when accessing data items during free learning (the intention categories of Chapter 1). An independent determination is possible by means of confidence estimates over response alternatives to questions about items lying ahead of those currently addressed (Table 3.2). A more readily quantified though less discriminating prediction is obtainable from the mechanically monitored free learning situation described in Chapter 1. Two indices, shown in Table 3.3, are the frequency of repetitious explorations and the extent to which immediate teachback order recapitulates the order in which items are addressed during free learning.

Retrospective determinations of style were carried out after learning in those phases of the design devoted to teachback and recall under interrogation. It is again possible to classify the students as comprehension learners or operation learners by the content analysis of teachback protocols (Table 3.3); for example, by ascertaining the extent to which the students do or do not have a picture of how they learned the subject, the topics they regarded as pivotal and whether or not ordered segments of learning became fragmented upon recall. In this particular study the retrospective

TABLE 3.4

Scores on Tests for Other Cognitive Traits *

		"Logical Meaning"	"Embedded Figures"	"Analogies"	Perceptual Discrimination	"Circles" Test Number of Items/ Number of Circles Used
Serialist Batch 1 (n = 18)	Mean	3.9	34.4	11.8	35.2	7.2/ 3.0
	SD	2.8	10.4	4.6	7.9	2.3/ 2.6
Serialist Batch 2 (n = 17)	Mean	3.8	34.2	12.8	35.5	6.6/ 7.8
	SD	2.6	11.4	3.9	8.9	1.9/ 2.2
Holist Batch 2 (n = 14)	Mean	4.1	36.7	18.8	30	10.5/12.6
	SD	2.5	12.1	3.8	6.2	2.9/ 3.1
Holist Batch 1 (n = 13)	Mean	4.5	38.4	18.3	36	9.9/12
	SD	2.3	9.4	3.3	8.6	2.4/ 2.4

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Statistical summary:

Holist Scores on the "analogies" test are generally higher than serialist scores ($p < 0.05$).

Holist scores on the "circles" test for "divergence" are generally higher than Serialist scores ($p < 0.05$).

indices are influenced by a variation in the teachback conditions interpolated during earlier phases (either "effective teachback" or an "ineffective teachback" which plausibly imitates the genuine teachback conditions but elicits indices of correct response that are not tied to giving an explanation, i.e., no explanation is encouraged or obtained.

Various tests (embedded figures, logical word-problem solving, analogy-completion) were administered to the same students in an attempt to discriminate styles. Modest and marginally significant correlations exist (Table 3.4).

2.2. The Spy Ring History Test

Style may be predicted quite reliably as a function of performance in conversationally administered tests (the Clobbits and Gandlemullers test of the previous monograph come into this category). One test which has proved extremely informative is called the "Spy Ring History" test. It has been administered to 5th and 6th formers at Henley Grammar School (65), students at the Architectural Association School of Architecture (40), and at various colleges and Polytechnics (50 or more).

The Spy Ring History test permits a student to learn a fairly complex subject matter by synoptic methods, particulate methods, or both, and the performance indices pick up the extent to which he has made use of a synoptic or particulate approach. (Either approach is useful and has its merits; full scoring is most easily achieved if a student has exercised and relied upon both methods, though it is possible to give correct replies on all of the test questions by adopting only one method.)

The test is based upon paired associate lists which indirectly specify a communication network linking spies, who (earlier version) are identified by alphabetic characters or (later version) memorable code names ("Abel" and "Boris" and so on). Ostensibly list-learning tasks of this type were employed by Hayes (1965) and later by Michon (1966). The serially presented list actually specifies a graph which can be recalled quite easily and which could be apprehended at a glance if it was (instead) displayed as a visual image. Some typical lists and networks are collected together in Fig. 3.2. The students are told that the lists determine pathways of communication between members of a spy ring during the last

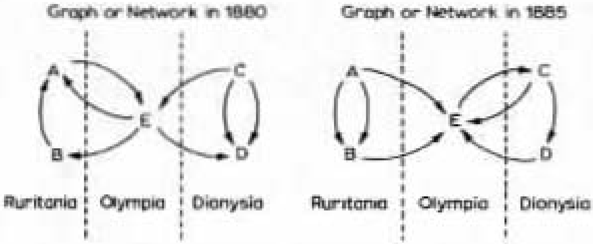

Fig. 3.2. Lists and graphs for Two Historical Epochs in the Spy Ring History test for Competence and Style. The lists are presented on tape. The network graph is not shown to the student.

century and the development of the ring is sampled at years 1880, 1885, 1890, 1895, 1900 (one network to each period in history). The networks all contain the same spies (in the same roles or positions) and are further described by a "countries" predicate, assigning each spy position to a "country" (Ruritania, Dionysia, Olympia, as imaginary European States). The several spy network graphs form a graph-product or "Cartoon" (Winner 1973). Parenthetically, the mathematical properties of Cartoons have been investigated by Winner. For example, some Cartoons are periodic (so that the morphism which relates one graph to the next in an indexed sequence leads to repetition of the same graph after so many cycles of iteration); some Cartoons are aperiodic. The five graphs in the Spy Ring History test belong to a Cartoon which becomes periodic after six repetitions (Fig. 3.3). This property, though convenient in designing the question format of the test, is not essential.

A student is required to learn, and later to explain, various features of the spy system history. The input he receives is in the form of paired associate lists, each specifying one period's spy ring configuration (for 1880, 1885, 1890; 1895, 1900), each list qua list, being learned to a criterion of faultless repetition, before the next is presented.

After learning, students are questioned in various ways. The object of the interrogation is to elicit complete information about the entire history including the minutae of each era or epoch (details of the questions and replies are given in Pask, Scott, et al. (Tech. Rep. 1974). Students can seldom provide all the informa-

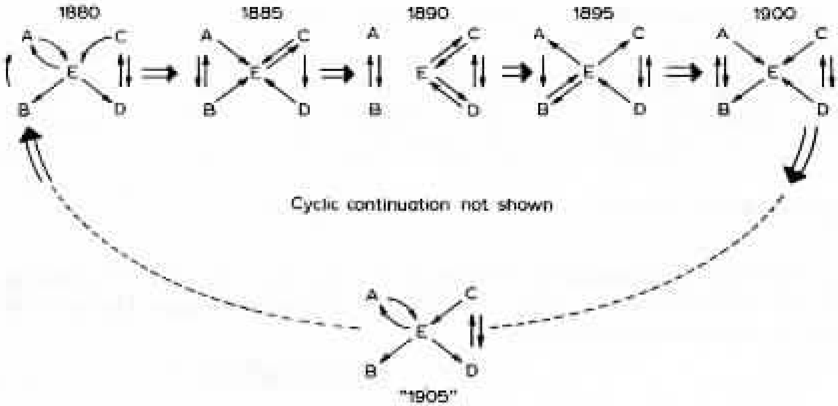

Fig. 3.3. The six graph cyclic cartoon and the five graphs that are presented for Historical Epochs 1880, 1885, 1890, 1895, 1900. The sequence is completed by "1905" at which point the process returns to 1880.

tion required, but typically give what they can in one of two patterns. Some students, classified as comprehension learners and potential holists, can answer broad questions like, "What went wrong with the spy system around 1885?" or even predictive questions relying for cogency upon the cyclic character of the six graph Cartoon from which the five graph Cartoon used in the test is extracted. For example, "Do you think that outstanding events are likely to be repeated in 1905; if so, why?" Other students, classified as operation learners and potential serialists, focus upon the individual networks or even the paired associate lists. For example, "How could Abel communicate with Boris in 1890; by how many paths, what are they?" or even "Draw the spy network of 1890". It should be emphasised that all students are required, if possible, to answer each kind of question as well as intermediary enquiries like, "Draw the boundaries of Dionysia, Olympia and Ruritania on a map", and "Say which of the agents belong to each country". The point is that comprehension learners will, if successful in this pursuit, work out the particulars by inference within the framework of global properties, whereas operation learners, again if successful, work out the answers to global questions by piecing together their local knowledge of particulars. These tendencies are reliably exhibited providing the overall score is high enough to provide a discrimination. If method of learning and success are both taken into account, the scoring categories are as follows.

(a) Operation Learner, Successful (in deriving global properties).
(b) Operation Learner, Unsuccessful (in deriving global properties).
(c) Comprehension Learner, Successful (in deriving local properties).
(d) Comprehension Learner, Unsuccessful (in deriving local properties).
(e) Both styles used successfully, called Versatile.
(f) Both styles and unsuccessful performance, or equally, neither style (that is, low overall score on the test as a result of which no discrimination is possible).

Certain qualifications and extrapolations are in order.

First, the test is "officially" biassed by the requirement of fully learning the original lists to favour recall of particulars even by the comprehension learner. Probably due to gross interference between the lists (which occurs if a student fails to assimilate them as the network graphs of historical epochs), the "official" bias is not, in fact, obtrusive.

Next, although the test is effective when personally (and conversationally) administered, it has not been possible to use it successfully in mass administration. Students treated in various ways as mass recipients do not achieve a high enough overall score. If they learn at all, interference dominates their recall.

Finally, it is extremely important to present a fairly rich semantic interpretation of the syntactic or formal structure. If the graphs are baldly interpreted as communication networks and the predicates as country boundaries, successful comprehension learners clothe the structure in further (redundant) properties of their own invention (a gambit previously observed amongst redundant holists) and use the imposed description scheme as a means for accessing the necessary data. Though we cannot prevent invention, and do not wish to do so, it is easier to quantify and discuss what goes on if the invention is tied to a known, rich and redundant account, which is open to scrutiny (anecdotes about the spies, pictures characterising the countries, and so on). We noted a similar requirement in the context of mechanical operating systems; it is necessary to ensure by aim validation that a student gives meaning to his aim topic, that he does not merely select an uninterpreted node in the entailment structure because of its index number or position.

One of the reasons why rich interpretation is crucially important emerged very much in retrospect and is discussed more fully in the sequel. At the least provocation, tasks like Spy Ring History are construed as "academic": as just another mental test or examination. The material *is* so construed during mass administration, and the construing is not altogether perverse. However, the result is crippling for it seems that institutions, the general nature of curricula, and subject matter presentation bias many students in their approach to the task concerned. They feel impelled to treat learning serially/operationally. To do so is a prerequisite for success; it is part of the task specification and regardless of their aptitude in the matter, they *do* tackle the task serially.

The belief has a large grain of truth in it so far as examinations are concerned, though no doubt the degree of restriction is over stressed, but obviously, the existence of the serial/operational bias defeats the attempt to discover which style a student is best able to use.

If these precautions are taken, the Spy Ring History test is a creditable predictor of style. Although the test was developed and piloted during the multi purpose study, it was seriously employed in later experiments involving the operating system INTUITION (Chapter 1) and, as judged by the subsequently observed learning strategies, the comprehension learners appear (in the operating system) as holists and the operation learners as serialists. The data are shown in Table 3.5 (notice, these students are drawn from a different population; the students in Tables 3.2 to 3.4 have no connection with those of Table 3.5.

2.3. Analogy Learning

How and what do the successful students learn?

It is argued that comprehension learning *must* involve valid analogy relations * and that operation learning *may* do so (recall

* "Analogy Relation" is used with more than usual rigour to designate a morphism between interpreted topic relations. The simplest morphism is a one to one correspondence, or isomorphism.

TABLE 3.5

Spy Ring History Test Scores for Students Whose Learning Strategy on INTUITION was Holist or Serialist *

Student Number	Holist or Serialist on INTUITION	Comprehension (A) (INTUITION serialist prediction)	Operation (B) (INTUITION holist prediction	Score on Neutral Question(s)	Success = $\frac{A + B + C}{300}$	Operation (+) Comprehension (—) bias = (A — B)/100	Versatility
1	S	66	20	60	0.49	0.46	0.01
2	S	80	0	80	0.53	0.80	0.001
3	S	54	15	54	0.41	0.39	0.04
4	S	76	5	80	0.53	0.71	0.03
5	S	72	0	68	0.47	0.72	0.005
6	S	60	25	60	0.48	0.35	0.09
7	S	83	5	76	0.55	0.78	0.03
8	S	79	0	70	0.50	0.79	0.006
9	H	70	90	76	0.79	—0.20	0.48
10	H	22	72	68	0.54	—0.50	0.11
11	H	16	85	76	0.59	—0.69	0.10
12	H	64	95	64	0.74	—0.31	0.39
13	H	92	82	94	0.89	0.10	0.71
14	S	100	5	100	0.68	0.95	0.05
15	S	56	0	60	0.39	0.56	0.003
16	S	62	10	66	0.46	0.52	0.04
17	S	84	15	84	0.61	0.69	0.11
18	S	78	15	80	0.58	0.63	0.09
19	H	88	90	86	0.88	—0.02	0.68
20	H	36	72	88	0.65	—0.26	0.23
21	H	18	74	68	0.53	—0.56	0.09
22	H	18	70	68	0.52	—0.52	0.09
23	H	82	72	84	0.79	0.10	0.50

* In Part From *British Journal of Educational Psychology* (Pask, 1976)

parenthetically the correlations of Table 3.4). Further, successful learning is an admixture of comprehension and operation learning in which one style or the other may be predominant.

Where are the analogies in the Spy Ring History test?

The different spy ring networks (for 1880, 1885, 1890, 1895, 1900) are held together by an analogy between the "graphs", each considered as an interpreted formal relation. Moreover, there is a very sound sense in which the entire Cartoon must represent an analogy. Without prejudicing this point, there are other optional analogies; for example, the "countries" may be regarded as analogous and so may subgraphs of a given graph. Any successful student must learn, and learn to use, certain analogy relations; he may, as a matter of choice, learn others. The successful comprehension learner places a great deal of reliance upon analogies; the successful operation learner makes less use of analogical inference and integration. A versatile student does all of this.

2.4. Cursory Globetrotting, Improvident Learning, and Versatility

Turn now to the less successful learners and consider their deficiencies, which are summed up by comparison with versatile behaviour in Table 3.6.

On inspecting the records and student replies to deeper interrogation, there appears to be a consistent trend. The comprehension learners who fail to make the grade (but have a high enough

TABLE 3.6

Relation of Operation Learning and Comprehension Learning to the Commonly Observed Pathologies; Globetrotting and Improvidence

		Comprehension learning	
		Yes	No
Operation Learning	Yes	Versatile	Improvidence
	No	Globetrotting	Failure

Versatile students, showing neither pathology, are successful as comprehension learners and operation learners. Although the defects are clearcut, the dichotomies in this scheme represent "dominances" or "biases"; for example, "Failure" students do not lack all comprehension/operation learning capacity, but execution of either process runs into difficulties.

overall score to merit comment upon their performance) use the purely descriptive components of an analogy and prove unable to grasp or transfer an underlying principle. The 1885 epoch is "like" the 1895 epoch because of some vaguely perceived similarity or just because they are a decade apart. The student fails to use or appreciate the genuine similarity of process which is common to the *different periods in historical development.* For the difference component of the analogy relation it would be possible to substitute all manner of given or invented distinctions. But there is, in this case, only one genuine similarity (in general, there are many legitimate similarities, but the class boundaries are strictly drawn). To phrase the matter so that it fits the idiom employed in the rest of the argument, it may be said that unsuccessful comprehension learners are able to describe a topic relation and thereby to derive its description from others, but they fail because they are unable to complete the derivation and build a concept. As a result, they are also unable to explain whatever is described. They comprehend only in the sense of making descriptions. They do not augment their comprehension by the operations needed to form a concept.

The less successful operation learners show signs of a converse difficulty. As a rule they are quite able to explain anything they know, using partial complementation ("there is a missing link" or "this spy must communicate with the others because I know the network is fully connected and the parts I can recall are disjoint"). Their stumbling block is inability to describe analogical relations between distinct entities, and it is usually manifest in an attempt to learn and recall the spy network of each epoch as a distinct graph. It is virtually impossible to learn and store five separate spy networks without destructive interference, and the problem is particularly acute if the student attempts to regard them piecemeal, ultimately, in terms of the original paired associate lists unmodified by any further structure. It looks as though the students in question are adept at concept building operations but are embarrassed by inability to comprehend descriptions.

Now the difficulties experienced by unsuccessful comprehension learners and operation learners parody two pathologies of learning which are quite generally recognised. I shall call these pathologies *Globetrotting* and *Improvidence.*

In its most pronounced and pernicious form Globetrotting leads to chains of tautologous constructions such as "a city is like an ant hill is like a beehive and that in turn is like a city". Unfortunately, the student is frequently unable to explain (and has no concept for) either a city or a beehive or an anthill; moreover, even if he does have a grasp on one of the concepts cited, he cannot say *how* ant hills and beehives are similar, so that he cannot validly derive the form of the remaining relations.

Such vacuous constructions are generally and rightly frowned upon. But it is important to realise that analogical reasoning is not in itself improper; on the contrary, it is essential to effective learning. Moreover, provided that a firm similarity is recognised, the analogical argument can proceed by way of many different descriptions, having the similarity in common but distinguished by employing various differences (period in history, character of the agents, social and political atmosphere). Finally, it is possible to base an analogical derivation upon a very terse description invoking but one difference, or upon a redundant description involving many related differences. Both redundant and irredundant descriptions are justifiable, though particular students have a preference for one or the other.

Improvidence is just as counterproductive as Globetrotting and is the reverse of it; namely, operation learning in the absence of comprehension learning. The pathology is clearly exhibited in connection with subject matter that is artificially (though perhaps usefully) carved up by traditional demarcation lines or established disciplines. For example, it is common practice to divide physics into neatly specified compartments such as "heat" and "light" and "electricity" and "mechanisms" and "magnetism"; to divide psychology into departments like "perception" and "motivation" and "learning". It would be stupid to reject these divisions; some description is required as a guide around the subject matter and these divisions are probably more defensible than most. But the existence of any divisions (and some divisions are surely essential) encourages the profligate deployment of cognitive resources manifest as Improvidence: failure to use the valid analogy relations that exist. Science, in particular, is replete with valid analogy relations, denoted by metaphors. Their formal similarities are captured in such notions as "Field" and "Dual" and "Equilibrium" and "Conservation of Quantity" or less widely applicable notions like "Conjugate" and "Valency" and "Inertial Frame".

Suppose an improvident learner is coming to grips with a general physical concept. For example, one concept we examine later in the book is "Oscillator". The student learns first about a mechanical oscillator, made from a spring, an attached mass, a frictional component and a forcing displacement. Probably at, or before, this juncture he learns a formal relation (the 2nd order differential equation governing all harmonic oscillators). Next starting from scratch, he proceeds to learn about an electrical oscillator made from a capacitance, an inductance, a resistive component, and a forcing potential variation. Again, the equation is pointed out, and it may be noted that the same equation covers the behaviour of mechanical and electrical oscillators. However, this fact, which establishes a strict analogy between the electrical and the mechanical departments, was not used in learning about electrical oscillators; nor will it be used in addressing oscillators in different departments.

An improvident learner wastes effort. It is quite unnecessary to learn and relearn the same formal relation in different universes of interpetation. Not surprisingly, the reconstruction of many ostensibly unrelated concepts gives rise to considerable interference. Topics in different departments (mechanics and electricity say) are treated like disparate lists. Without recognising the valid correspondences (mass ↔ inductance, friction ↔ resistance, and so on) that relate the departments, there is little positive transfer (as there is when the analogy is appreciated), and any transfer that takes place becomes negative if the correspondences are distorted.

For these reasons, improvidence is culpable, though, because of the curricular/academic bias noted in Section 2.2, students are less often blamed for it. We comment that an improvident student who does make progress must be an outstandingly good operation learner; otherwise, he would proceed at a snail's pace. Further, his success depends upon regarding the departments as rigid categories. Without comprehension learning the valid correspondences, this is the only way to avoid negative transfer founded upon arbitrary and usually false similarities.

Globetrotting and Improvidence are both well recognised by practicing teachers, and it is probably gratuitous to quantify evidence supporting their existence. Data on their frequency of occurrence are available from recent studies of examination essays (Pask, Scott, et al., Tech. Report, 1974).

2.5. A Classification of Learning Styles

On the basis of introspection and commonsensical observation, it seems that any coherent act of learning involves at least two processes. First, a concept is described in terms of other descriptions. This operation, dubbed *Description Building* or *DB*, is equated with appreciating a topic. So, for example, a student able to appreciate an aim topic (chapter 1) builds a description of it; in general, people can describe whatever occupies their attention. Secondly, there is a concept building (or according to our formulation) a *Procedure Building* operation, for short *PB*, as a result of which a concept is constructed to realise the description.

Tentatively, a "coherent act of learning" means an *understanding* (again in the technical sense), and we posit that both the first and the second operations (*DB* and *PB*) are involved in achieving an understanding. These loosely stated speculations are backed up by a more detailed and well-grounded discussion in Chapter 5, and in Section 3 of this chapter. But this statement is sufficient for the immediate purpose.

Again, introspection, supported by common observation, suggests that descriptions of concepts may be global or local. A global description is typically redundant, but an irredundant description spanning many other concepts or based upon ancestors that are united by an analogy relation will also count as global. Learning strategies that rely upon global descriptions tend to be holistic. In contrast, a local description is parsimonious; it rests upon a minimal set of supporting topics. Learning strategies relying upon local descriptions are serialistic.

The global/local distinction was introduced after completing the multi purpose experiments, though it was suggested by the results obtained. The distinction was first actively employed during the current experimental series using the INTUITION operating system installed in schools and colleges (Henley Grammar School, Twickenham Polytechnic, AA School of Architecture, Furzedowne College, Streatham).

By combining a bias to *DB*, a bias to *PB* or both with the global/local distinction, we obtain the categories of learning style shown (and related to operation/comprehension learning) in Table 3.7. Although the *DB* process is related to comprehension learning and the *PB* process to operation learning an adequate discrimination also relies upon a test for global and local orientation.

Various criteria are used as global/local discriminators. When students have completed learning they are asked to recall how they learned. Amongst other things, students are required to classify cards labelled with names of the topics they have encountered, using personal construct descriptors elicited by the Repertory Grid technique. Such descriptions are reliably global or local and the distinction tallies with a discrimination based upon the adicity or complexity of topic configurations dealt with during learning (high adicity = global, low adicity = local). Finally, the adicity measures correlate with four tests for personality traits which were administered during the earlier part of the study: a test for "Cognitive Complexity", Bieri et al. (1966); a test for "Attention Deployment", Mendelsohn and Griswold (1966); a test of cognitive "Flexibility", Robertson (1974); and a test for "Self-Consistency", Gergen and Morse (1967). Summary results are shown in Table 3.8.

One notable feature of the global/local propensity is that it is not confined to situations in which concepts are understood (though it is manifest as an aspect of understanding). A global/local orientation also pervades learning where understanding is not elicited, such as adaptation, problem solving and probably the

TABLE 3.7

A Proposed Classification of Learning Styles and Its Resolution in Terms of Versatility, Comprehension Learning and Operation Learning

	DB + *PB*	*DB* Bias	*PB* Bias
Global	Versatile or Comprehension Learning	Comprehension Learning	Operation Learning
Local	Versatile or Operation Learning	Operation Learning	Operation Learning

Assignment as Versatile depends upon the conditions of observation. All behaviours in "*DB* + *PB*" category are deemed "Versatile" but the globally oriented versatile learner appears to have a bias to comprehension learning and the locally versatile learner a bias to operation learning.

TABLE 3.8

Results from Tests of Cognitive Style for Low Adicity and High Adicity Learners *

	Score on Bieri Test for Cognitive Complexity	Score on Test for Attention Deployment	Score on Flexibility Test	Score on Self-Consistency Test	
Mean	155	0.36	10	38	"Low Adicity" Learners (n = 5)
SD	22	0.06	4.9	27	
Mean	108	0.44	6	45	"High Adicity" Learners (n = 5)
SD	14	0.12	1.7	8.3	

* Printed with permission from the *British Journal of Educational Psychology*. Significant correlations ($0.05 > p$) are as follows. Attention deployment and Bieri (0.63), attention deployment and flexibility (0.65), flexibility and Bieri (0.55), self-consistency and attention deployment (0.65), and self-consistency and Bieri (0.79).

exercise of perceptual motor skills. We conjecture that global or local orientation is a property of the brain regarded as a processor rather than the cognitive processes executed in the brain.

3. DISPOSITION COMPETENCE AND LEARNING STYLE

Style is a convenient but general rubric which conceals two quite different structural distinctions. On the one hand, style encompasses gross differences like comprehension/operation learning and the global/local orientation, as well as relatively precise characterisations of learning strategy, for example, holist/serialist and the subcategories redundant/irredundant holist.

On the other hand, style encompasses both a student's disposition to adopt a given type of learning strategy, as well as his competence to execute a strategy of the chosen type.

3.1. Refinement of Style as Holistic or Serialistic

To refine the grain of characterisation it is necessary to control the learning situation with greater stringency either by insisting upon effective teachback, or by employing an operating system (CASTE or INTUITION) and the subject matter representations (entailment structure and task structures) that support its regulatory action. It will be recalled that an operating system secures two basic conditions, namely:

(a) All topics that are learned are also understood (it is, of course, possible that a student may not be able to "learn" under these circumstances and opts out).

(b) Cooperative assistance is provided in measured quantity so that, so far as possible, understanding is enabled. Further, the minimum amount of cooperation is provided in order to obtain this result.

Teachback approximates these conditions with much of the subject matter representation held in the participant experimenter's head. For small subject matter areas, the approximation is close and teachback using verbal rather than non verbal explanation is more flexible. For large subject matter areas, such as the extended probability theory material used in Henley and London, teachback becomes impracticable.

There is ample evidence that Condition (a) Understanding is satisfied and that it predictably gives rise to a permanent body of concepts. Table 3.9 shows various differences between effective and ineffective (or simulated) teachback obtained in the multi purpose experiments; Table 3.10 shows comparative retention scores for these two conditions. The data in Table 3.11 tell a similar story, in this case, for the operating system INTUITION and the subject matter of probability (students from Henley and London). Learning and the incidence of defects are compared for the case when the full operating system is in action and the case when the understanding requirement is replaced by a demand for correct response but no explanation (the parallel to ineffective teachback).

The effect of Condition (a) and Condition (b) (or simply of "experience" in the INTUITION operating system) is a reliable positive transfer. Records of time per topic and unsuccessful explana-

TABLE 3.9

Summary of Results for Study of Effects of Matching/Mismatching *

Student Group		Matched with Gandlemuller program	Mismatched with Gandlemuller program	Matched with Operon program	Mismatched with Operon program
Batch 1 Operation Learners (like serialist)	Means SDs	90.9 3 7 (n = 9)	33.0 8.4 (n = 9)	90.8 3.8 (n = 9)	34.9 6.1 (n = 9)
Batch 1 Comprehension Learners (like holist)	Means SDs	91.0 3.6 (n = 7)	45.6 5.4 (n = 7)	47.0 6.3 (n = 7)	90.0 1.8 (n = 7)
		Matched with Operon Program	Mismatched with Operon Program	Matched with Probabilistic Inference Program	Mismatched with Probabilistic Inference Program
Batch 2 Operation Learners (like serialist)	Means SDs	92.0 3.7 (n = 9)	35.3 8.8 (n = 8)	98.0 20.1 (n = 8)	32.6 9.8 (n = 9)
Batch 2 Comprehension Learners (like holist)	Means SDs	92.9 4.0 (n = 7)	38.8 8.0 (n = 6)	93.7 3.4 (n = 6)	43.0 11.1 (n = 7)

* Printed with permission from *British Journal of Educational Psychology* (Pask, et al.).

Statistical summary:

1. Each student's matched performance > mismatched performance ($p < 0.001$, Wilcoxon Matched Pairs Signed Ranks Test).
2. Aggregate difference: matched task scores > mismatched task scores ($p < 0.001$, Mann-Whitney U-Test).

TABLE 3.10

Summary of Results for Study of Retention Using Effective and Ineffective Teachback (post-teachback score is represented as a % of pre-test score) *

Student Group		Effective Teachback on Gandlemuller Program	Ineffective Teachback on Operon Program
Batch 1 Operation Learners (n = 9) "like serialist"	Means SDs	99.0 5.4	38.0 12.2
Batch 1 Comprehension Learners (n = 7) "like holist"	Means SDs	101.1 7.1	56.0 8.8
Batch 1 Operation Learners (n = 9) "like serialist"		Ineffective Teachback on Gandlemuller Program	Effective Teachback Operon Program
	Means SDs	51.0 12.1	109.0 5.2
Batch 1 Comprehension Learners (n = 7) "like holist"	Means SDs	57.0 9.8	104.0 6.4
Batch 1 Operation Learners (n = 9) "like serialist"		Effective Teachback on Operon Program	Ineffective Teachback on Probabilistic Inference
	Means SDs	84.1 26.4	47.9 19.9
Batch 2 Comprehension Learners (n = 7) "like holist"	Means SDs	98.7 23.9	71.0 16.1
Batch 2 Operation Learners (n = 8) "like serialist"		Ineffective Teachback on Operon Program	Effective Teachback on Probabilistic Inference
	Means SDs	40.1 13.9	103.5 13.8

TABLE 3.10 (continued)

		Ineffective Teach-back on Operon Program	Effective Teachback on Probabilistic Inference
Batch 2 Comprehension Learners (n = 6) "like holist"	Means	62.0	116.0
	SDs	13.1	30.8

* Printed with permission from the *British Journal of Educational Psychology*.
Statistical summary:
Each student's effective teachback results > ineffective teachback results. Differences are significant for all students (and for all operation learners and comprehension learners treated as separate subgroups) ($p < 0.001$, Wilcoxon Matched Pairs Signed Ranks Test).

tions of topics for two of the modules in "Extended Probability Theory" are shown in Table 3.12. They belong to 11 closely studied 6th form students from Henley grammar school. Assistance given during work on Module 2 is no more than (and in most cases very much less than) the assistance furnished during work on Module 1. A similar effect was observed using CASTE in terms of mean uncertainty and mean correct belief which are continually sampled in this operating system. These data are also shown in Table 3.12. Positive Transfer is beneficial, if the operating system is viewed as a training device for making students aware of how they learn. However, we suspect that transfer involves an increase in versatility, at any rate for some students, and this blurs some of the predictions essayed in the sequel.

The cooperation provided in pursuit of Condition (b) is of two kinds: first, provision of a description of the topics to be learned (from the entailment structure and the explore/aim transactions), and secondly, provision of demonstrations which specify how a concept should be built from other concepts that are already understood. Clearly, the first kind of assistance is an external surrogate for description building (*DB*) operations the student would otherwise have to perform, and the second kind is an external surrogate for procedure building (*PB*) operations.

In other words, instead of introducing the *DB* and *PB* compo-

TABLE 3.11

Learning by Students of Differing Competence Profile in INTUITION System

	Student No	Test Score	Mean Time per topic (mins)	Index of Overall Success	Bias for Operation (−) or Comprehension (+) Learning	Versatility Index	
Entailment	1	100	6	0.68	0.95	0.05	
Structure	2	95	11	0.39	0.56	0.003	
Full	3	95	11	0.46	0.52	0.04	
Explanation	4	100	8	0.62	0.69	0.11	
Demanded	5	100	13	0.58	0.63	0.10	
	6	100	5	0.88	−0.02	0.68	
	7	90	9	0.65	−0.36	0.23	
	8	95	8	0.53	−0.56	0.09	
	9	100	10	0.52	−0.52	0.09	
	10	95	10	0.79	0.10	0.50	
Means		96.5	9.3	0.56	0.10	0.19	Subjective Estimate of Incidence of Globetrotting (% of no. of topics tackled)
SDs		4.0	2.1	0.12	0.35	0.21	
Entailment	11	72	9	0.60	−0.48	0.17	1
Structure	12	80	15	0.54	0.66	0.06	6
Multiple	13	38	12	0.57	0.70	0.07	14
Choice	14	52	7	0.47	0.61	0.02	8
Questions	17	60	18	0.57	0.72	0.05	10
Only	16	90	8	0.67	0.64	0.19	7
	17	100	14	0.77	0.16	0.46	5
	18	70	14	0.59	0.65	0.10	0
	19	65	13	0.55	0.66	0.06	15
	20	50	12	0.51	0.49	0.05	15

							Subjective Estimate of Incidence of Improvidence (% of topics tackled)
Means		67.7	12.2	0.52	0.48	0.12	
SDs		21	2.6	0.07	0.18	0.07	
No Entail-	21	50	16	0.56	−0.38	0.12	15
ment	22	46	14	0.73	−0.08	0.38	5
Structure	23	65	10	0.62	0.62	0.16	0
Multiple	24	90	12	0.62	−0.42	0.18	20
Choice	25	70	15	0.65	−0.18	0.26	10
Questions	26	65	15	0.56	−0.60	0.11	12
Only	27	40	13	0.50	−0.47	0.07	21
	28	72	11	0.53	−0.34	0.13	17
	29	80	8	0.74	−0.12	0.39	2
	30	90	14	0.55	0.22	0.14	8
Means		67	12.8	0.60	−0.16	0.19	
SDs		17	2.8	0.07	0.22	0.06	

Statistical summary:

Group 1: test scores greater than Groups 2 and 3 ($p < 0.001$, Mann Whitney U-Test) Mean times per topic are significantly less than those of groups 2 and 3 ($p < 0.5$, Mann-Whitney U-test). *Group 2*: mean times per topic are less than Group 3, the difference is not significant.

For *Group 2* there is a significant negative rank correlation ($p < 0.01$) between test scores and estimated incidence of globetrotting.

For *Group 3* there is a significant negative rank correlation ($p < 0.05$) between scores on "holist" questions of the Cartoons Test and estimated incidence of improvidence.

TABLE 3.12

Gross Transfer of Learning Skill Connected With the Use of the INTUITION and CASTE Operating Systems. Study of Different Groups of 12 and 10 Students

	INTUITION			
	Mean Time/Topic (mins)		Frequency of Unsuccessful Explanation	
	Module 1	Module 2	Module 1	Module 2
Means	9.7	6.6	0.12	0.02
SDs	2.9	1.4	0.05	0.02
(n = 12)	CASTE			
	Mean Δ H_i		Mean Δ θ_1	
	1st $\frac{1}{2}$	2nd $\frac{1}{2}$	1st $\frac{1}{2}$	2nd $\frac{1}{2}$
Means	0.97	0.22	−0.72	−0.22
SDs	0.49	0.23	−0.22	−0.06
(n = 10)				

Statistical summary:
INTUITION mean time/topic module 1 > mean time/topic module 2 ($0.01 > p$, sign test). Unsuccessful explanation module 1 > unsuccessful explanation module 2 ($0.01 > p$, sign test).
CASTE system Mean ΔH(1st) > Mean ΔH(2nd) ($0.005 > p$, Mann-Whitney U-Test) and Mean $\Delta\theta$(1st) > Mean $\Delta\theta$(2nd) ($0.005 > p$, Mann Whitney U-test).

nents of learning on intuitive grounds (Section 2.5), it would have been possible to argue that *DB* and *PB* are genuinely distinct *because*, in an operating system, it is possible (and necessary if the system works) to furnish differential *DB* and *PB* assistance to the student.

Thus augmented (by *DB* or *PB* as needed) and thus restricted (to understand each topic, if necessary with assistance given), students who learn at all adopt a learning strategy which may be classified as holist or serialist. Moreover, their tendency to adopt one type of learning strategy or the other is predictable from indices of learning style.

Specifically, the refined categories of holist and serialist are manifestations in an operating system (or in teachback regulated conversations) of the more general characteristics of style. Our hypothesis is crystallised in Table 3.13 and 3.14. Of these, Table 3.13 posits the combinations (of *DB/PB*, global/local) yielding categories of learning style, and Table 3.14 shows the behaviour predicted if a student of a given stylistic category learns in an operating system. The behaviours are resolved as holistic or serialistic, and we emphasise that this distinction is established unequivocally in terms of marker distributions on the entailment structure and transaction records. The prediction of a versatile student is that he may adopt either a holistic or serialistic learning strategy, by instruction or on whim. Moreover, he may change strategy if the subject matter is changed. But, having once adopted a holist/serialist strategy, cognitive fixity will make him stick with it whilst he is learning in the same conversational domain. The stylistic categories "G-Null" and "L-Null" are predicted "not to learn"; that is, augmentation is insufficient to induce understanding.

TABLE 3.13

Stylistic Categories

	Versatile Students Comprehension and Operation Learning	Comprehension Learners	Operation Learners	Failures
	DB and *PB*	*DB* not *PB*	*PB* not *DB*	Neither *DB* nor *PB*
Global	*GDB* + *GPB*	*GDB*	*GPB*	G-Null
Local	*LDB* + *LPB*	*LDB*	*LPB*	L-Null

The categories are shown as dichotomous in the interest of clarity. They are supposed, in fact, to represent polarities; for example, "*DB* not *PB*" means "Dominantly *DB*" and "*PB* not *DB*" means "Dominantly *PB*". With the caveats noted in the text, stylistic categories are *Competence Profiles* and are, henceforward, referred to as *Competence Profiles*.

Apart from this last prediction, there is ample evidence that exactly these behaviour patterns do occur and are related, as proposed, to indices of comprehension learning, operation learning, and the global/local propensity (previous tables). Typical student records are shown in Fig. 3.4 and Fig. 3.5 to indicate the level of detail at which these patterns are identified.

It would be inappropriate to cite pattern frequencies until more work has been done; the case is made just as convincingly by noting that all the patterns of Table 3.14 have been observed with varying frequency (minimum 4 patterns) over more than 50 students (run during the ongoing field studies) and that the undetermined entries (apart from G-Null or L-Null) can be resolved by resource to the way that analogical topic relations are learned. We

TABLE 3.14

Behaviours Predicted in an Operating System

Competence Profile on Stylistic Category	Predicted Learning Strategy		Exploration Predicted	Demonstration Required
GDB + GPB	Versatile	Redundant Holist	Many	Few
		Serialist	Few	
LDB + LPB	Versatile	Irredundant Holist	Undetermined	Few
		Serialist	Few	
GDB	Redundant Holist		Many	Many
LDB	Irredundant Holist		Undetermined	Many
GPB	Serialist		Many	Few
LPB	Serialist		Few	Few
G-Null	No Understanding		Undetermined	Many
L-Null	No Understanding		Undetermined	Many

return to this matter in Chapters 4, 5 and 6, when the theoretical backbone has been discussed.

The power of this explanatory scheme is increased by extending Table 3.14 to accommodate situations in which the cooperation offered by the operating system, Condition (b), is systematically cut down and/or the demand for understanding, Condition (a), is systematically relaxed. Behavioural predictions for the wider range of situations are shown in Table 3.15.

The corresponding experimental conditions are realised as follows (A, B, C, D, E refer to the columns in Table 3.15).

A. Strict conversation, Fully Fledged Operating System, as in the upper group of Table 3.11.

B. The requirement for non verbal explanation (model building) on each topic marked as understood is replaced by a correct response criterion on a test made up from questions spanning the relevant topic. The overall impact of this modification is shown in Table 3.11. The more intimate results are those predicted in Table 3.15; versatile learners (*GPB* + *GDB* or *LPB* + *LDB*) are not significantly affected, for they explain topics whether or not they are required to do so. Much the same is true of operation learners (*GPB* or *LPB*) who build concepts but do not easily build descriptions. However, the comprehension learners (*GDB* or *LDB*) are strongly influenced by Globetrotting (prohibited in a fully fledged operating system that calls for non verbal explanation) which becomes a common occurrence and accounts for most of the deterioration in performance revealed by the middle lower group in Table 3.11.

C. Explanations are required, but the surrogate *DB* operations are no longer made available under these circumstances. Any understanding (and each topic must be understood) depends upon a *DB* operation performed by the student himself. To realise this condition, the entailment structure is denuded; all indications of analogy relations are deleted, as are the corresponding explore transactions. As a result, learning is slowed down. Versatile performance is least impaired, comprehension learners (*GDB* or *LDB*) are not greatly influenced; both kinds of learner can build their own descriptions. In contrast, the operation learners (*GPB* or *LPB*) become improvident and the deceleration of learning shown (lowest group) in Table 3.11 is mainly due to this fact.

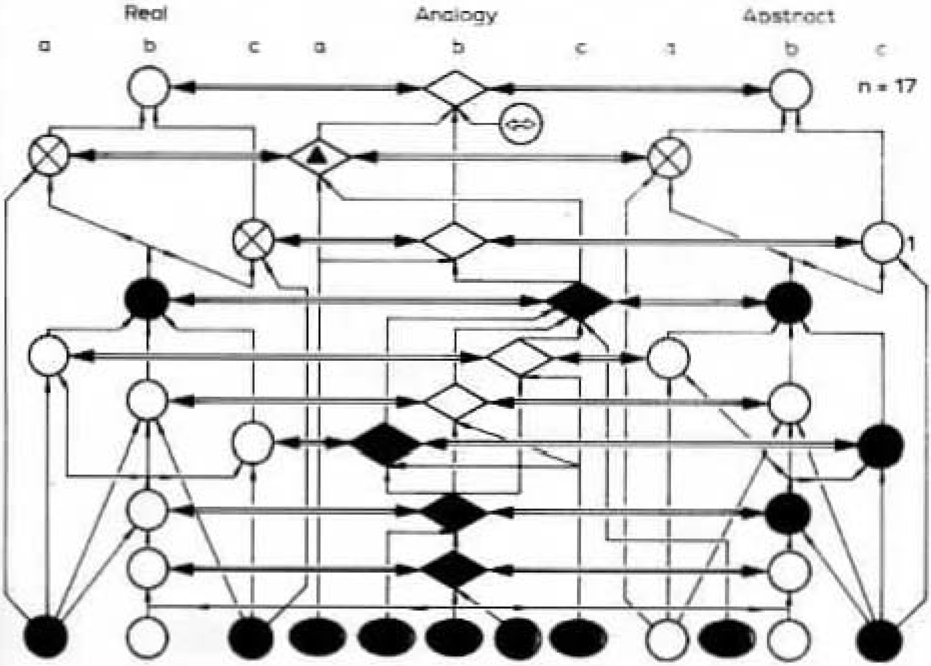

Fig. 3.4a. (Figs. 3.4b,c and d are on the following pages.) Occasions n = 17, n = 18, n = 19, n = 20 in typical holist learning strategy (▲ = aim, ○ = goal, ● = understood). Numbers index "explore" transactions.

D. To provide the condition "No *PB* assistance" it is necessary to preserve the explanation requirement but to abrade the demonstrations. Experiments are in progress and do not deny the predictions of Table 3.15, given the caveat that the table is based on the (false) simplifying assumption that students *do* obtain demonstration aid, when in fact they *may do* so. Our main prediction is substantiated; namely, that comprehension learners (*GDB* or *LDB*), break down completely. The prediction is definitive compared to the others, since learners of this class must have recourse to demonstrations and fail to achieve understanding if this assistance is withdrawn.

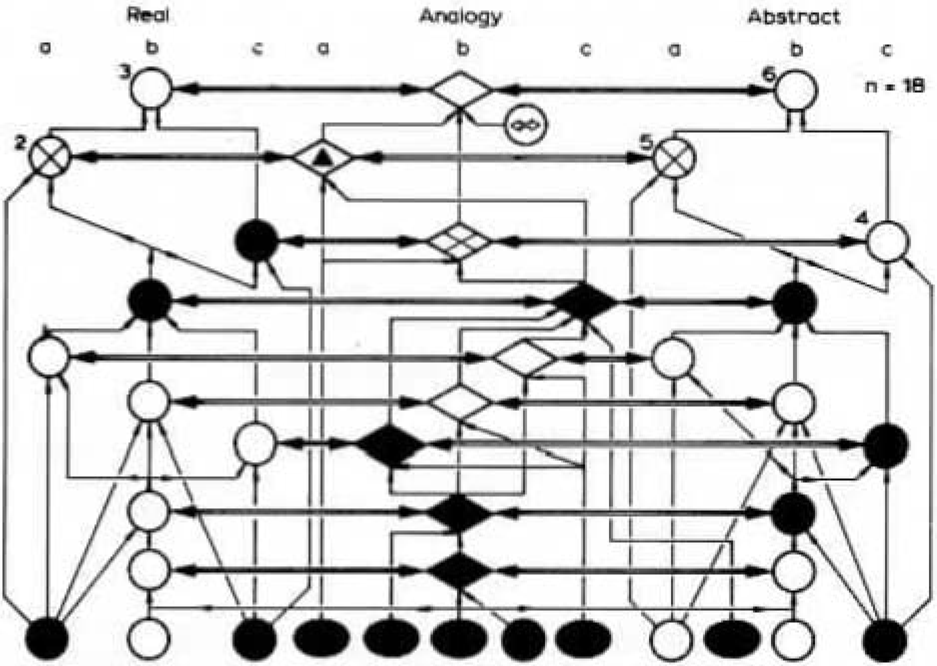

Fig.3.4b.

E. Trivially, explanation is not demanded and no assistance is explicitly furnished. The condition is approximated by a free learning situation or by various unmonitored learning situations.

It is probably legitimate to extrapolate the categories of holist and serialist, which are strictly defined for an *operating system* to yield a characterisation of learning strategies with respect to *any conversational domain*. The characterisation is illuminating since it exhibits a distinction between the "comprehension learning/operation learning" dichotomy and the "holist/serialist" dichotomy in a way that secures a place in the overall scheme for "redundant holists" as compared to "irredundant holists". Further, the present characterisation, though worded differently, is in close agree-

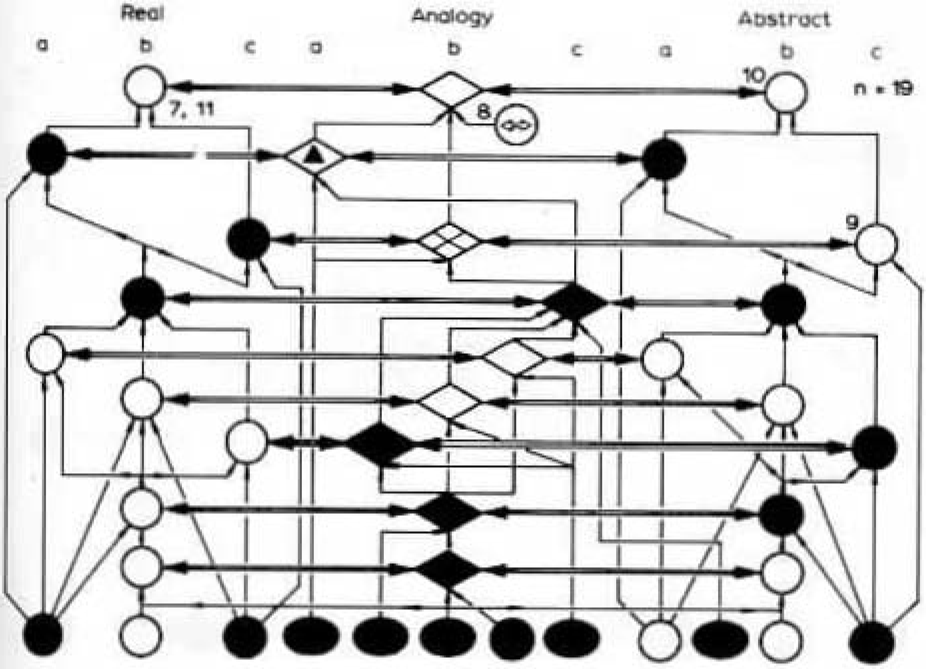

Fig. 3.4c.

ment with the operational definitions of a "holist strategy" and a "serialist strategy" as given in the previous monograph.

Seen in the context of a conversational domain, with cyclic derivations exhibited, the holist/serialist strategies differ as follows: Students employing either learning strategy come (of necessity) *to understand some cyclic and reconstructible substructure*, a Gestalt. The substructure is a syntactic (derivational) entity. Whereas the holist chooses as large a cyclic substructure as possible, the serialist chooses the smallest possible cyclic substructure. If the mesh is pruned, as it is before inscription upon an entailment structure, the "size maximising" case appears as the aim, goal, understood marker distribution of Fig. 3.4, which tallies with the diagnostic criterion for holist learning in an operating system. Similarly, the "size minimising" configuration gives rise to the

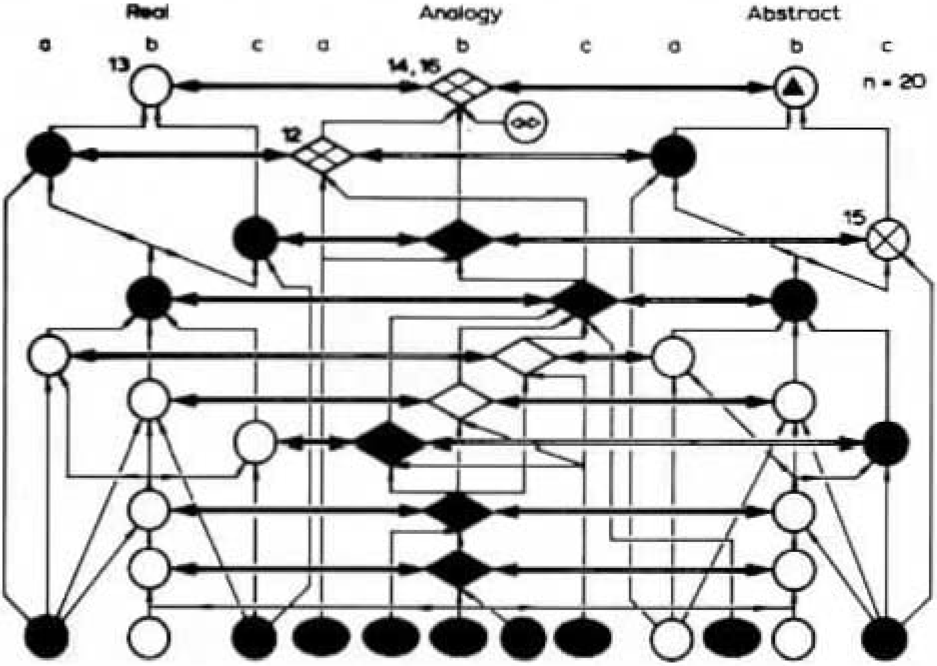

Fig. 3.4d.

marker distribution of Fig. 3.5, which tallies with the diagnostic criterion for serialist learning in an operating system. In either case, the "sizes" are syntactically specified. "Distance" is measured in terms of the length of derivations (entailment chains) and do not take into account the number or diversity of semantic descriptors which are evaluated or assimilated as a result of learning. This latter and unaccounted index is particularly important for those cyclic substructures which represent analogy relations. For example, someone acting as a holist but also anxious to adumbrate many distinctions established on semantic grounds would, of necessity, aim for analogical topic relations; and conversely, someone equally holist who is not anxious to deal with many semantic distinctions would avoid analogy relations though he could not eschew them completely. We posit that a redundant holist is a

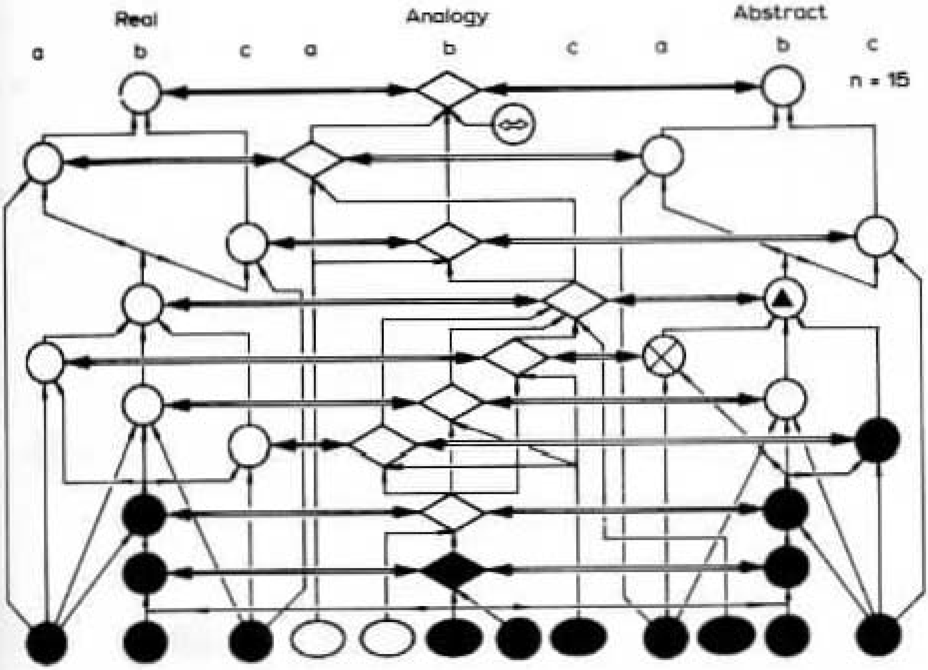

Fig. 3.5a. (Figs. 3.5b,c and d are on the following pages.) Occasions n = 15, n = 16, n = 17, n = 18 in typical serialist learning strategy (▲ = aim, ○ = goal, ● = understood). Numbers index "explore" transactions.

holist who does process many semantic distinctions, either those of exhibited analogy relations or, failing that, analogies of his own invention. Conversely, an irredundant holist either steers clear of analogies (when possible) or uses only a minimal number of semantic distinctions in order to make sense of the syntactic or formal similarity expressed by an analogical topic relation.

The distinction "comprehension learning/operation learning" is subtly different. Comprehension learners, with their bias to *DB* operation, tend to use analogies as the scaffolding of knowledge whenever possible. As holists, they are inclined to be redundant holists. At any rate if the bias to comprehension learning is extreme. In intermediary cases (and, a fortiori, for versatile students),

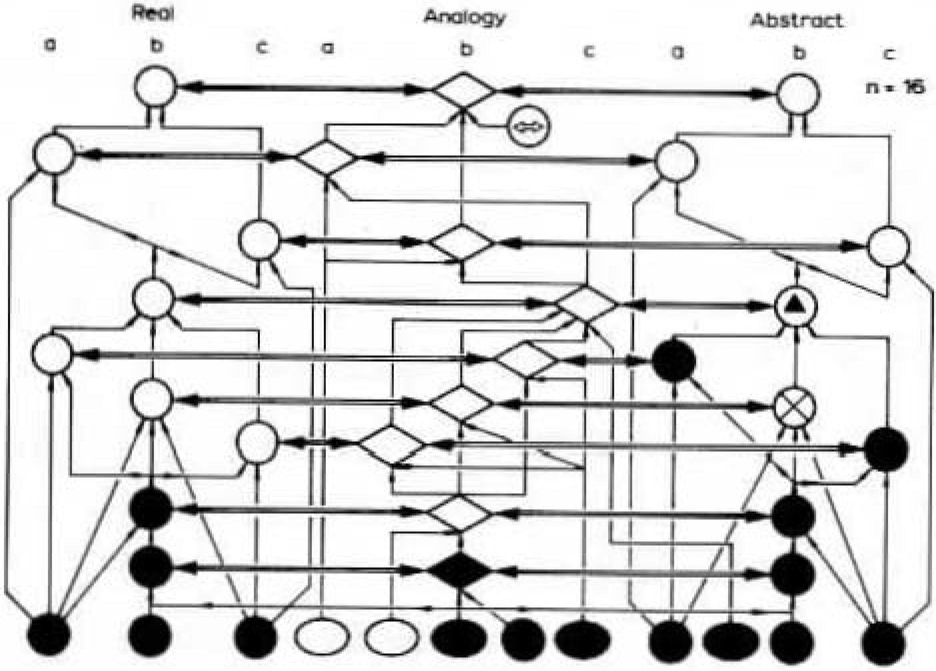

Fig. 3.5b.

they may figure either as redundant or irredundant holists. On the other side of the coin, operation learners with their bias to *PB* operations tend to learn other-than-analogical substructures and to stick them together with minimal recourse to analogy relations. In extreme cases they are in register with serialists. But the intermediary cases (a fortiori, versatile students with an operation learning bias) may be either serialists or irredundant holists.

3.2. The Distinction Between Disposition and Competence in Execution

Style predisposes a student to a learning strategy; once the learning strategy is adopted it is stabilised as a result of cognitive fixity. This dogma is supported by data from all the experiments, but is most dramatically evidenced by the multi purpose experi-

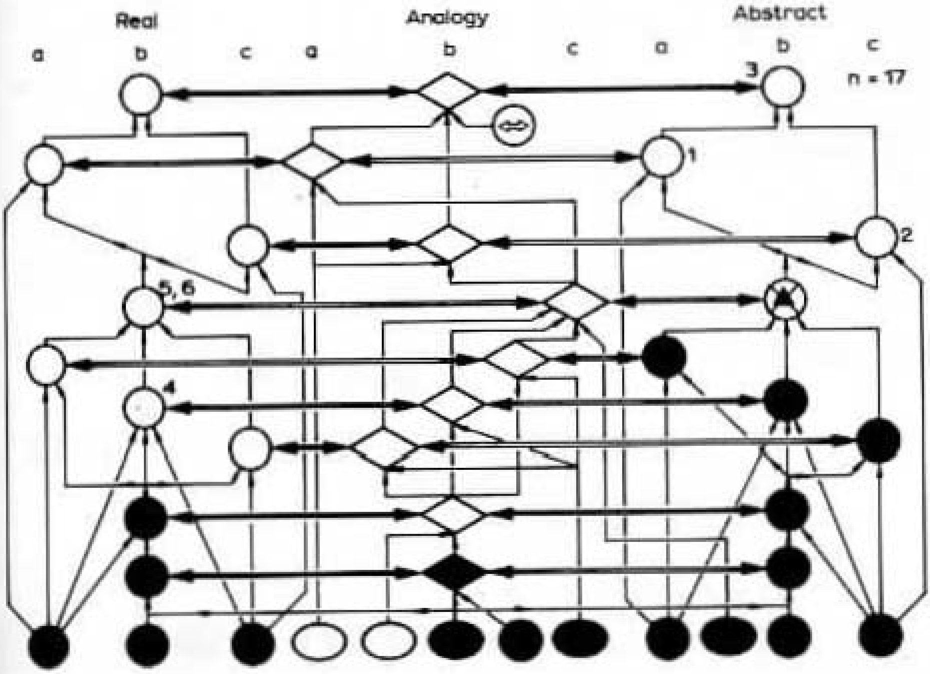

Fig. 3.5c.

ments where students characterised as holist or serialist with respect to learning one subject matter were found to exhibit the same learning strategy when mastering quite different subject matter. The stability is exhibited by choice of learning strategy and the effect of instruction which is matched or mismatched with respect to the original assignment as holistic or serialistic (Tables 3.1, 2, 3, 9, 10). Such a marked stability is surprising, for it is only possible to predict on theoretical grounds that cognitive fixity will stabilise an originally selected learning strategy whilst the student is attending to the *same* conversational domain.

The overall result of mismatching a teaching strategy (imposed upon a student) and a learning strategy (which he has adopted) produces a high magnitude impairment; in this respect the data from the multi purpose experiments are in accord with the previous

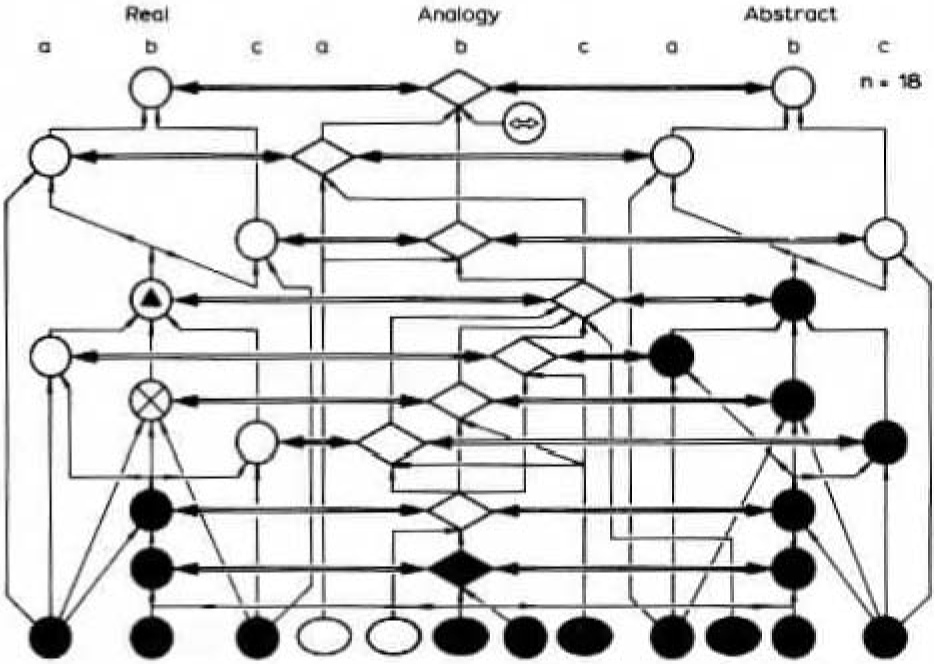

Fig. 3.5d.

monograph and provide valuable confirmation of the result using a larger sample of students. But the stability data say little about *why* the learning strategy was chosen (this choice is non committally attributed to style).

Can we dissect style into a conative part, reflecting a student's desire or disposition to adopt a learning strategy (later stabilised by cognitive fixity), and a part to do with his competence in executing this strategy? Only if the chosen learning strategy is one which the student is fitted to execute would it be legitimate to relabel the stylistic categories of Table 3.3 and Table 3.14 as "competence profiles". If it were the case that students are only disposed to do whatever they are competent to do, then dissection would be fruitless. Contrariwise, if a dissection is meaningful then

TABLE 3.15

Predictions Arising from Combinations of Competence Profiles and Constraints upon an Operating System in Which Learning Takes Place

	A	B	C	D	E
	(Exp. Full *ES*.)	(CE no Exp. Full *ES*)	(Exp. Denuded *ES*.)	(Exp. Full *ES*. RD)	(CE No Exp. Denuded *ES*)
L-Null	Flounders about. Often eventually succeeds but experience probably changes the competence profile.	Serialist. Aim = Goal. Path dictated by displayed *ES*. Rote learns. Recall (if any) depends upon path.	Uses denuded *ES* display like headings in a book. Rote learns topics. No content recalled	Fails to learn.	Usually flounders Only learns if told what to do, if one topic at once, and if concept construction is spelled out.
LPB	Takes aim topics from displayed *ES*, preferring serial path. Gives explanations. Few demonstrations.	Serialist. Aim dictated by displayed *ES*. Takes little notice of analogies between topics unless forced to do so. Can explain topics even though explanation not demanded.	Improvident and repetitious learning. Takes no account of analogies (not displayed in denuded *ES* but might be inferred). Can explain topics learned.	Serialist. If any topics learned can explain them.	Learns algorithmically, or sequences of chained conditional responses.

TABLE 3.15 (continued)

	A	B	C	D	E
	(Exp. Full *ES*.)	(CE no Exp. Full *ES*)	(Exp. denuded *ES*.)	(Exp. Full *ES*. RD)	(CE No Exp. Denuded *ES*)
LDB	Strongly serialist. As far as possible learns in departmental manner. Hesitates over, but gives, explanation. Many demonstrations	Serialist. So far as possible learns in departmental manner. Fails to explain.	Improvident and repetitious learning. Takes no account of analogies (not displayed in denuded *ES* but might be inferred). Hesitates over, but gives, explanations.	Fails to learn.	Learns formal pattern of data structure, but not content. List-like recall.
LDB + LPB	Uses all entailment relations but bias to serialist learning. Can explain topics learned. Few demonstrations.	Serialist. Can explain topics even though explanation not demanded. Few demonstrations.	Effective. Constructs missing derivations with bias to axiomatic or formal extrapolations. Gives explanations.	Serialist. Explains topics learned.	Versatile. May have "learning to learn" ability. Predicted "convergent" bias to innovation.
G-Null	Flounders about. Often eventually succeeds but experience probably changes the competence profile.	aim = goal. Topics scattered. Rote learns. Recall (if any) depends upon path taken.	Uses the denuded *ES* display as pattern. May learn this pattern but no content recalled.	Fails to learn.	Usually flounders. Only learns if told what to do in broad (perhaps pictorial) manner and if concept construction is spelled out.

GPB	Takes aim topic from displayed *ES*, preferring departmental path, if permitted. Gives explanations Few demonstrations.	Holistic. But next aim dictated by displayed *ES*. Topics scattered. Can explain topics even though explanation not demanded	Fills in missing analogies between topics by valid relations. Can explain topics learned	Globetrotting over constrained path in *ES*. Explains topics learned.	Does intuitive problem solving or learning. May learn perceptual motor skills.
GDB	Strongly holistic. So far as possible relies on analogical relations. Hesitates over, but gives, explanations.	Holistic. Cursory globetrotting. Learns usually vaccuous quasi analogies or similarities. Fails to explain.	Fills in missing analogies by often vaccuous similarity relations. Globetrotting. Fails to explain.	Globetrotting in *ES* Fails to explain.	Learns meshlike (often pictorial) formal patten of data structure but not content. Broad associative recall.
GDB + GPB	Uses all types of entailment relations. Bias to holist learning. Can explain. Few demonstrations	Holistic. Can explain topics even though explanation not demanded. Few demonstrations	Effective. Constructs missing derivations with bias to valid analogical relations. Can explain.	Holistic. Explains topics learned.	Versatile, may have "learning to learn" ability. Predicted "divergent" bias to innovation.

there is an issue of "internal matching" that deserves consideration; matching or mismatching between the learning strategy chosen and the student's competence (in contrast to matching between style and an "externally imposed" teaching strategy).

There is an abundance of hard-to-quantify evidence in favour of the latter point of view. Unless special precautions are instituted a student's choice of learning strategy does not necessarily reflect his mental competence.

It happens that proper safeguards have been incorporated, more by luck than foresight, in most of our experiments. During strategy determination, the student is taught to appreciate his own learning process and its deficiencies; if he shows signs of ineffective learning, an internal mismatch is suspected and the student is encouraged to try a converse strategy. In the Spy Ring History test the subject matter is richly described and rendered unlike test or examination material for which the student is likely to entertain beliefs and convictions about the officially good way of learning. Finally, and crucially, the experimental work is backed up by rather detailed and prolonged individual interviews (most of the comments in the next section stem from interview data).

Because of this, we are fairly confident that the stylistic categories act as "competence profiles", and that terminology is henceforward employed.

4. NOTES ON THE CHARACTER OF COMPETENCE MECHANISMS

Because of the precautionary measures, it is also possible to detect the existence of internal mismatching, engendered by belief or indoctrination.

As noted, counterproductive dispositions are quite common and seem to generalise over more subject matters than suspected, in fact, over all academic or institutional subject matters. (Just as a learning strategy is stable over the diverse subject matters used in the multi purpose experiments.) It is true that exactly the same induced dispositions are productive if they tally with the student's ability to execute the class of learning strategy he is disposed to adopt. The case of mismatching between disposition and competence is more easily observed: the student adopts a definitive learning strategy without encouragement; he is manifestly unable to execute the learning strategy he so readily adopted. At that point the experimenter becomes alive to a difficulty and probes the issue of disposition and competence in greater depth.

The converse (productive) form of induced disposition is noticeable amongst science-stream 6th formers. Due to the subject matter load and a certain preference for unfolding scientific discoveries in a historical sequence, these students receive markedly serial instruction, and an incidental premium is often placed upon operation learning. Some 30 percent to 50 percent of the students in this group are aware of having a disposition to adopt one class of learning strategy before the requirement to exteriorise such a thing, explicitly, is forced upon them by contact with the operating system INTUITION. Of the students who *do* make a definitive choice, nearly all state quite dogmatically that the study habits which determine their disposition were induced by the teaching and the content or arrangement of the subject matter. Further, they are satisfied with their disposition and are, in fact, expert in adopting serially biassed learning strategies (though, as a rule, these students are outstanding learners and have the versatile competence profile *LDB* + *LPB*).

The only holist students in such a class seem to belong to the group who do not *have* an initial disposition. On scrutinising records and reports they do not exhibit the excellence (in science subjects) of their colleagues. However, there is a very appreciable improvement in their performance, when, after competence testing, they are advised to adopt a particular learning strategy *; sometimes the recommendation is holist, and if so, the students often turn out to be versatile with the profile *GDB* + *GPB*. Data from individual interviews indicate that the students who "had no disposition" but "turned out to have a holist bias" have actively rejected the serial/operational mores of the science course; just as their peers actively accepted a serial/operational disposition.

The real difficulties begin only with less sophisticated students; either those who are less likely to be versatile or those who are more inclined to accept conventions in an unquestioning manner. Students from technical colleges and some students in the 5th

* Performance with respect to learning in the experimental system. We do not yet know how long the improvement lasts or how well it generalises to other school subjects.

form of the same school come under this denomination, and again judging from the interview data, members of this population are the people most likely to have dispositions out of kilter with their competence and to have the disposition just because they are told, directly or indirectly, to do so. The commonest mismatch between disposition and competence is (for the reasons already stated) a serialist disposition unfitted to a holistic competence, which for profiles other than versatile is a major impediment. An interesting concomitant is that such students often learn extracurricular subject matter in a competence-suited manner and learn it with far greater efficiency. The reader who is sceptical on this point is invited to compare the (often arcane) extracurricular knowledge of a representative student with his academic knowledge. Using any reasonable measure of the amount known, academic knowledge forms a small proportion of the total, and the difference is enhanced by weighting this ratio with the time spent since becoming acquainted with (say) astrology or anthropology, and the time spent in learning (say) computer science.

All this highlights the question, "where is competence found?" According to our theory, one aspect of competence is part of a cognitive organisation (the student as a P-Individual) which has a collection of useful and stable concepts. This is the competence ingrained by cognitive fixity and induced by social interaction. At this level, there is no difference in kind between disposition and competence. Though they need not run in the same direction, they often do so, and if not, remedial action can be taken to bring them into accord. Moreover, the result of this action should also be perpetuated by cognitive fixity. On the other hand, there appears to be a further and substantially immutable factor in competence which often runs counter to induced disposition. As a conjecture, this is a property of the student's brain as a processor, not of the student as a cognitive organisation (a P-Individual). The evidence to hand, though still scanty, does not deny the hypothesis that this factor is the "global or local" orientation, tapped by measures of "adicity" and "recall".

5. RATE OF LEARNING, ANALOGY RELATIONS, AND VERSATILITY

There is appreciable variation in the interval required to master a subject matter. To some extent this variation can be accounted for in terms of competence and the existence of previously acquired concepts. To some extent the rate of progress can be modulated by processor parameters (physiological changes and specific conditioning, for example).

However, scrutiny of the records, either in the multi purpose or the school based experiments, discloses an interesting fact. Students who learn rapidly are students who use (and understand) valid analogy relations.

Like many of our findings, this one states the obvious (at any rate with hindsight). The only way to change mastery rate by many orders of magnitude is to employ analogical relations between disparate topics. It is a truism of education, the entertainment industry, and journalism alike. Hence, Improvident learning is slow but sure and may be the norm; Globetrotting is hazardous if not self defeating; understanding analogies is the only way to get on.

The analogy relations may be discovered by an expert and displayed (in an entailment structure or some other subject matter representation); if so, the student learns them straight forwardly, and for this purpose, either of the versatile competence profiles is sufficient. There is some evidence that the training effect of experience in an operating system is chiefly due to inducing versatility (from other profiles) and exercising it in this manner.

On the other hand, the analogy relations may be discovered or invented by a student, as they must be if he is coping with an unstructured environment and structuring it on his own account.

Students who have an art of learning in general, who have learned (or been taught) to learn are able to play the discovery and invention trick. Certainly, versatility is a prerequisite for the art of learning. Moreover, insofar as it fosters versatility, experience in an operating system teaches people to learn. But it will be argued that a further prerequisite for the art of learning in general is an ability to compare descriptions and concepts built under different perspectives and that the proper training ground for this ability is a many-aim operating system (discussed in Chapters 4 and 6; described in Chapter 7 in the context of course assembly and innovation).

Of all the structures that might be imposed upon an unstructured environment by someone who has learned to learn, the most important are formally expressed as analogy relations. Just as these analogy relations shortcut the tedium and repetition of Improvident learning and lead to rapid mastery of a predigested subject matter, so also, analogy relations are the glue required to make sense of an otherwise chaotic reality and to stick together theories (and, a fortiori, scientific theories) which otherwise are disparate essays bringing order only to small regions of what may be known.