Chapter 1

A Comparative Survey of Conversational Methods

1. INTRODUCTION

The basic theme underlying a conversation theory has been voiced repeatedly. There are precedents for many of the tactics adopted in the work of Piaget and (independently though contemporaneously) Vygotsky (see, for example, Piaget's 1962 *Comments* upon reading the English translation of *Thought and Language*). These pioneers, their colleagues, and students, including Inhelder, Papert, Luria and Minskaya, developed conversational methods for probing, observing and exteriorising cognitive events which normally remain concealed. All the techniques rely upon a participant experimenter in the role of a tutor, an interviewer or an interrogator; in each case, of someone who shares in the mental activity of the respondent. Two special methods are representative of their studies: the "paired experiment" and the "questioning interview", and two aspects of these methods are of special interest: the elicitation of explanatory responses and the representation of thoughts and discoveries.

1.1. "Paired Experiments" and Concrete Operations

The "paired experiment" is a paradigm chiefly exploited by the "Russian school". A respondent faces a problem situation in concert with the participant (who is there to aid, abet, provoke and encourage the respondent, as well as to record what goes on). The problem situation is embodied in a physical artifact such as a puzzle or a mechanical gadget. Whatever the artifact may be, it is jointly perceived by the participants (respondent and experimenter) and is open to external observation. The experimenter poses problems, some of them designed to place insuperable obstacles in the respondent's path, concerned with the function of the artifact or extensions of the artifact. The respondent replies either verbally or by manipulating the artifact. In a typical session the questions are "How" and "Why" questions and the answers, if forthcoming, are explanations or constructive responses that refer to the artifact or a conceivable modification of the artifact. Insofar as some enquiries are designed to pose unsolvable problems, there are occasions upon which the respondent appeals for help and the experimenter then performs a demonstration or points out a principle or suggests some way in which the artifact could be modified to serve a different purpose. The immediately relevant point is that all statements, whether verbally uttered or not, can be interpreted either with respect to the problematic artifact as it stands or some other construction which could (at least ideally) be constructed from a similar apparatus. By this means, the participants are able to reach an agreement and the basis for their agreement is exteriorised for impartial scrutiny.

In the mid 1920s Piaget employed similar techniques; children (the participating respondents) focussed their dialogue upon physical situations. Though experimentally convenient, such an arrangement may also hamper flights of fancy and imagination which are just as important constituents of thinking as sober minded essays. Hence it was noted (and similar comments recur, from time to time, in the literature) that the physical realisation is optional. Experience seems to have shown, however, that an anchor of some kind is nearly mandatory if the dialogue is to make sense; for example, Piaget himself stresses the importance of a concrete situation with metric rods, water jars, or whatever to reify abstractions like the conservation of quantity, area and volume. One line of argument lays emphasis upon the respondents' age. *Children* need to concretise their operations; the requirement for a manipulable artifact is bound up with a well-established developmental phase (concrete operational/formal reasoning). No doubt there is a great deal of truth in the suggestion that children must explain manipulatively because they are unable to give coherent verbal explanations (we return to this matter in Chapter 11). But the truth is almost certainly qualified. Age or developmental phase exacerbates a difficulty latent in any participant experiment, even using respondents old enough to reason formally and probably embarrassed by the requirement to map (for them) natural abstractions onto the manipulation of an artifact. Unless an intermediary exists and responses are referred to it, certain sorts of agreement are unachievable and certain (participant) agreements, even if achieved, are inherently ambiguous to an external observer.

It is worth investigating what this intermediary (so far, represented as an artifact) must be. Need it, for example, be a physical contrivance (puzzle, water jars, playing board)? Could it be something far less restrictive? An affirmative reply is furnished by a recently translated body of work by Landa (1971) which made systematic use of paired experiments (though the phrase "paired experiment" is not employed in the description).

Landa is concerned with the way that older children and adolescents learn the logic of sentance manipulation, subject to grammatical and semantic constraints. In particular, he is anxious to show that expertise depends upon knowing and using valid inference and exclusion principles represented as algorithms. At one stage in the discussion, Landa ponders over the question of whether he is teaching "grammar" or "logic" (he notes, for example, that grammarians might think it odd or even wasteful to incorporate logic in the syllabus). His conclusion is extremely telling. You cannot teach logic. You can only teach an interpretation of logic and one such interpretation is in the universe of grammatical transformations (other universes of interpretation include engineering systems or mathematical structures). Logic can surely be learned in any interpretation, conceivably a specialised variety of logic. It cannot be learned *in vacuo*. The converse argument also applies: Unless logic *is* learned there is *no* learning.

Clearly, "learning" is used in a special sense in this statement (and the statement is a terse accentuation of Landa's point of view). However, this sense is quite defensible and is an implicitly accepted tenet of the argument presented in this book (in Chapter 6). "Logic" is used in rather a specialised way also, and this usage uncovers the depth of Landa's commentary. For, although he appears to be talking about a logic of classes and propositions (and sometimes is doing so) the logical schemes interpreted in the universe of grammatical transformations are themselves algorithmic.

The interpretations are processes. The logic is a logic of questions and actions and the universe is a dynamic entity capable of accommodating events (the logic is amongst the non-classical logics of Chapter 4, the interpretation is like the universe of compilation and interpretation introduced at this juncture).

The critical feature of the intermediary problem situation is thus seen to be a semantic interpretation of the language employed for the dialogue. In order that a conversation shall take place, the rules of the language must be understood, in the notation of the previous monograph the rules and syntax of L (this condition being part of the experimental contract). In addition, there must be a semantic interpretation, whether concrete or symbolic, and this interpretation is generally more than the "interpretation" of classical model theory and mathematics (i.e., a set or sets of objects). It is an interpretative medium in which programs (algorithms) may be compiled and executed. By far the most versatile and well developed concrete medium is a computer equipped with Papert's (1970) LOGO peripherals and able to intrepet LOGO programs. As noted in the previous monograph, execution of the program is either a visually displayed, or mechanical, activity (depending upon the peripheral devices that are used).

1.2. Representing Knowables

In the Piagetian interview and to some extent the paired experiment, the participant experimenter probes the respondent in order to draw out his concepts of the problem situation; for example, by asking why an event takes place or what would happen if some feature of the situation changed. Such exploratory questioning must be backed up by knowledge of a subject matter field if corrective assistance is to be furnished. It may or may not be the case that this knowledge is functional and in this respect the experimenter's brief is quite liberal. For example, if we want to discover what the respondent knows about physics, then (since this is an empirically-based subject) the experimenter must be abreast of things as they are. But it is just as legitimate to follow an imaginative trail and discuss how the respondent thinks. Here, and in general, it is only necessary that the experimenter has a greater cognitive facility than the respondent, supported, if possible, by a broader knowledge of history, mythology or the possibilities of invention.

Although this specification is pleasingly flexible, it suffers from the defect that the data structure in the experimenter's head is inaccessible to an external observer, except that some of it is externalised in dialogue. Moreover, this data structure is inaccessible to the respondent, except for the information he gains by questioning the experimenter.

Ideally, both participants should be able to point out items in the data structure in a mutually comprehensible manner so that lines of explanation can be started and questioning initiated by either party. Various schemes have been adopted and do not in practice unduly restrict the interchange of ideas, since in any actual experiment the possible topics are limited (if only as a result of having an interpretive medium as the intermediary problem situation). In particular, a subject matter specification, especially if redundant, is completely unobjectionable for studies of learning, where the respondent is a student, and the specification stipulates what may be learned. So, for example, it is possible to stack up index cards or pictures bearing on a redundantly specified subject matter, these cards or pictures being accessed by either participant.

The obvious and valid objection is that the indexing which, in effect, describes the data items is arbitrarily imposed upon the conversation. It is due to an outsider, rather than the participants themselves. This objection, which bears just as strongly upon tutorial/learning experiments as any others, can to some extent be met. At least it is possible to play various tricks which effect a compromise between allowing for a participant-based description and an acceptable standard of observability.

1.3. Descriptions of Data Base

Most studies which employ explicit representations of knowables take it for granted that a description is given and understood by the participants. Commonly this description is just sensibly chosen (Bruner, Goodnow and Austin's 1956 study of concept acquisition); sometimes, it is based upon a factor analytic resolution of semantic scales evaluated by a population of respondents (for example, using Osgood et al. 1957) "semantic differential" techniques. Amongst the exceptions to this rule is work by Thomas and his associates in which exploratory conversations, often concerned with learning, are based upon mutually generated descriptions. Such descriptions are obtained from one respondent by applying the repertory grid sampling procedure (see previous monograph or Chapter 3, 6 and 7) to elicit personal constructs (Kelly 1955). * If the situation warrants serious attention to the description schemes of both participants, it is possible to use a more sophisticated routine (exchange grids) in order to compare their personal constructs and to circumscribe a region of mutual agreement. By iterating the routine, it is also possible to generate a shifting description scheme in which the area of mutual agreement moves around as the conversation proceeds.

One study will exemplify the method and indicate its main features. The term projects of art school students were the topic of conversation (between an experimenter and the students in a class). Each project produces a crop of artifacts, usually bits of sculpture. These artifacts, made by the participating students to crystallise their work, form the objects over which the personal constructs are elicited. If the conversation ranges over a wider compass, the set of objects is augmented, commonly by other pieces of artwork, from museums, galleries and representative practitioners in the field.

Each respondent determines his own personal constructs over the entire set of objects. During the conversation the constructs of the participants are compared, as a rule with the aid of exchange grids formed by requiring one participant (A) to rate or evaluate construct names used by another participant (B), and vice versa requiring B to rate A's construct names. Various means are employed to limit the proliferation of constructs and to condense those parts of the description that are agreed as mutual (i.e., to arrive at a core of possibly novel constructs which A and B rate in a similar manner).

Without going into the technical details, it is clear that this procedure gives rise to a participant-generated description scheme which, by rating the core of constructs over any desired objects, can be extended to cover any dialogue bearing even remotely upon the term project; hence, a description of the sort looked for in the last section. However, there is more to it than that.

* It will be recalled that a personal construct is elicited by presenting triads of objects, requiring a predicate (the personal construct) which separates one member of the triad from others, rating the values of this predicate over all objects, and iterating triad selection.

The conversation refers to a term project and its intellectual ramifications; in general to artifacts that might be produced under comparable conditions rather than the gaggle of artifacts that were produced and are used as objects. The conversation refers, in other words, to an interpretative medium: the concrete or symbolic production system in which art school students are able to model their notions of reality. This universe of interpretation is not given, as it would be in a classical experiment. It is specified by the participants who choose properties (the personal constructs or the mutually acceptable core) and later instantiate their values. Let us say the classical experiments determine a description scheme "from down to up"; that is, a set of objects or events are chosen as a universe of interpretation, together with predicates that name properties or relations between these elementary entities. Conversely, an experiment such as Thomas's determines a universe "from up to down". Certain knowables, signified by the (repertory grid) objects, are ostended by the participants; personal constructs are elicited as predicate names which are rated or given values. Instances of these values (or, by repeating the procedure, the values of an arbitrarily fine grained mesh of constructs) are instated as elements of one or more universes. The universe of interpretation is thus generated by the participants, rather than being given. Usually the several participants have distinct universes. Some areas remain private but others are placed in a common domain by dint of mutual agreement about a core of constructs. This core is the conversational universe of discourse and it may change, both in extent and refinement, as the conversation proceeds.

1.4. Interpersonal Interaction Techniques and IPM

In Piagetian interviews, the conversation sometimes refers to the problem situation, the knowables, or the interpretative medium; sometimes, to the participants. So, for example, some stretches of dialogue express hypotheses due to the respondent or the experimenter about solving a problem; other stretches of dialogue express hypotheses due to the respondent about the experimenter (or *his* view of the problem); and vice versa, hypotheses due to the experimenter about the respondent. Since the discourse takes place in a (possibly restricted) natural language, it is difficult to disentangle hypotheses about facts or depersonalised ideas (objective or *it* referenced hypotheses) and interpersonal ideas (*I* or you referenced hypotheses).

If the IPM ("interpersonal communication test") method and its associated comparisons (previous monograph and Chapters 6 and 7) are used as communication aids in a conversational experiment, this method provides a filter that isolates interpersonal hypotheses for special scrutiny; for example, A's hypothesis about solving a problem (P) and B's hypothesis about solving P figure as personal-objective hypotheses A(P) and B(P) that are duly matched for factual agreement. In contrast, A's hypothesis about B's hypothesis about P, written A(B(P)) is an interpersonal hypothesis and so is B(A(P)). They, and higher level interpersonal hypotheses A(B(A(P))) and B(A(B(P))) are matched to determine mutual comprehension and appreciation. When the idea of a conversation is analysed, the segregation of the interpersonal component in dialogue is very important; just why will be discussed in Chapters 4, 6, and 8. It is doubtful whether an interchange devoid of an interpersonal component should be deemed a conversation at all. Yet one of the outstanding hazards attached to refining the conduct of a conversation is as follows: the well-intentioned refinements produce an arid situation stripped of interpersonal exchange.

This danger is present even when imposing the modest codification required to elicit and make sense of personal constructs. Hence, it is noteworthy that the experiments mentioned in the last section avoid this danger by incorporating a tacit IPM interchange. The exchange grid procedure *is* such a thing. To see this, replace P by a repertory grid (G). Let A(G) be the grid elicited from A: a matrix with columns labelled by objects, rows labelled by A's construct names and entries that are the values given by A to each of his constructs on each of the objects. Let B(G) be the grid elicited from B, with columns identical to A(G), but with rows labelled by B's construct names and entries comprising the values given by B to these constructs. Mutual agreement over a description (of what may be known or discussed) is obtained by requiring A to rate (give values to) B's constructs — which results in an extended matrix A(B(G)) — and requiring B to rate A's constructs — yielding, as a result, an extended matrix B(A(G)). Now, instead of independently eliciting a further level of mutual hypotheses (the trick employed in the IPM test), the participants compare and consider the matrices A(B(G)) and B(A(G)) in order to select or generate constructs that belong to the mutually agreed core; in the light of the mutual information, fresh constructs are invented and the ratings of the existing constructs are modified, as the exchange grid procedure is repeated.

1.5. Conversation Theory and Conversational Methods

The conversation theory described in the previous monograph unifies these well-established conversational methods. To some extent, it adds to the repertoire of techniques and increases the precision with which postulates about conversations are stated.

Surely, these claims require qualification. Of the experimental or tutorial arrangements described in the previous monograph, one ("teachback") is a specialisation of the natural language interviews used by Piaget, Vygotsky, and their followers. The special condition secured (namely, an understanding of each topic addressed by the participant) is believed to be fundamental, but that belief could be faulted. The other arrangement, a computer monitored Course Assembly System and Tutorial Environment (CASTE) does unequivocally secure understanding. But the mechanisation which is a practical prerequisite for this much rigour and objectivity may be unwelcome. Although the system does exteriorise hidden cognitive events, it imposes certain restrictions upon the participants. Though these restrictions are vastly less hampering than the constraints imposed by an other-than-conversational method of enquiry, it can be argued that CASTE conversations are oddly stilted ones. We are sensitive to the potential criticism and feel it is sometimes justifiable. Hence, much of this book (notably Chapter 6 onwards) is devoted to a systematic relaxation of the constraints upon the dialogue. This endeavour pays an unexpected dividend: the emancipated system allows for transactions that are, in practice at any rate, prohibited during fettered conversation. For example, even in the Piagetian interview, there is a tacit presupposition that the participants have one and only one focus of attention at once, corresponding in CASTE to one and only one aim at once. Our relaxations permit many aim operations and, in practice, several sorts of many aim transactions are realised.

Concerning unification, the other claim for conversation theory, the experimental arrangements ordained by the theory embody and integrate the components highlighted in previous sections of this chapter. It is true that a complete embodiment only occurs in relatively sophisticated arrangements of the kind discussed later in this book. But all the experimental systems (CASTE, for instance) are derived as specialisations of the general and sophisticated case; conversely, the general case is presaged by "teach back" and the course assembly system (EXTEND) described in the previous monograph.

For instance, the modelling facility featured in all the systems and spawned by conversation theory is the interpretative medium of Section 1.1 (for housing problem situations). The entailment structure is a representation of what may be known (Section 1.2), and insofar as it is used in an evolutionary fashion (EXTEND or a system to be introduced called THOUGHTSTICKER), its description is both personalised and "from up downwards" (rather than "from down upwards") as proposed in Section 1.3. Many of the experimental or tutorial systems incorporate an IPM like component (Section 1.4). In fact, this component so underpins the operation of the complex systems that the "interpersonal interaction" paradigm gains a novel significance.

Finally, conversation theory maintains that the basic unit for psychological experiments is a conversation, and carries this dogma to a rational conclusion in the hypotheses about cognitive organisation and P-Individuals. The other theorists do not seem to make this point as definitively or to pursue its consequences to the same extent. Our thesis is, perhaps pedantically, explicit. Hopefully, it reflects the views of our coworkers in the field, amplifying rather than distorting their meaning.

2. OPERATING SYSTEMS

The various experimental "arrangements" such as "teach-back" and CASTE are henceforward clustered under the title "operating systems". This section describes the operating systems currently in use for "one aim at once" conversations; roughly for conversations in which the conversational domain is fixed and the student has only "one focus of attention at once". Evolutionary systems in which the conversational domain, represented as an entailment structure, may be enlarged or modified are discussed in Chapter 3, where the discussion is again confined to "one aim at once" operation. Many-aim systems are considered in Chapter 6, after some theoretical prefatory material has been presented (Chapter 4 and Chapter 5 mostly).

Section 2.1 is a brief recapitulation of the work reported in the previous monograph. In Section 2.2 to 2.5 we describe the mechanically regulated one aim operating system employed in recent studies. Both this system and CASTE have been augmented as a result of experience by incorporating several features; notably, a much richer semantic interpretation obtainable by explore transactions, a procedure called aim validation, and a series of special transactions for dealing with analogical topics.

2.1. Recapitulation of Basic Features

A strict conversation takes place between participants using a conversational language L. For convenience, L is stratified into levels $L = L^1, L^0$. On theoretical grounds, the unit of a strict conversation is held to be an event called an *understanding* of a topic. An understanding is evidenced by an explanation of the topic and the derivation of the topic; the former in terms of L^0 transactions and the latter in terms of L^1 transactions. An explanation specifically evidences the existence of a concept and *is* the listing of a program which represents this concept. A derivation specifically evidences either a memory (defined as a concept that reconstructs a concept) or else the construction of the concept as it is acquired in learning. The period occupied in reaching an understanding is called an occasion, and if occasions are to be ordered so that topics (though accessed in any order) are understood in sequence, then it is necessary to introduce the caveat "one and only one focus of attention at once".

In "teachback" the explanations and derivations required to substantiate an understanding are elicited humanly, using a slightly stilted form of English in place of L. The subject matter which contains the topics is represented in a description scheme (a map like display where each topic has a location and the locations are classified by descriptive properties). Under these circumstances some essential aspects of the subject matter data base are out of sight in the participant experimenter's head.

CASTE is a largely mechanised system. Explanations are elicited non-verbally as model-building operations in one or more modeling facilities, which are dynamic processors in which programs or models are executed.

It is particularly important to notice that an explanatory model built by a student is a program listing; so is a demonstration offered by a teacher or obtained from the regulatory heuristic on request. The behaviour of these programs when they are executed is quite distinct; it is their behaviour which does or should (if correct) satisfy the topic being explained (modelled) insofar as it computes or "brings about" or "satisfies" the underlying topic relation.

The subject matter representation for CASTE is a *conversational domain*. This consists in a formal (or syntactic) network imaging a thesis expounded by a subject matter expert; the topic relations appear in this network as nodes standing for derivations. Since a thesis is any orderly collection of derivation paths, a topic relation is linked by derivation chains to others. As a matter of convenience, the student sees, on a display called the *entailment structure*, only a simplified form of this network (the details of derivations are smudged under a common entailment connection). This simplified mesh is permissive. It represents what may be known if certain other topics are understood. Explicitly, the mesh asserts what may be known with the guarantee (obtained by processing a thesis before it is deemed legal and represented) *that the known topic(s) is (are) learnable and memorable.*

To each node in the mesh is attached through a data link (not an entailment connection), a structure which says *what may be done* to bring about the topic relation represented at the corresponding node. In the previous monograph these structures are referred to as Task Structures *TS*; since they act as a source of demonstrations. They may also be used for comparative purposes (a student's explanatory model is matched against the *TS* to determine its rectitude). The task structure is literally a collection of programs or sequences of commands for setting up *models = compiled programs* in one or more modelling facilities (either as demonstrations given to the student or as explanatory models he submits) and mere correctness, unqualified, is secured if the model can be executed and if, on execution, it satisfied the relevant topic relation.

In the previous monograph we distinguished the prescriptive and descriptive role of such a structure attached to the node of *topic* i by the notations $TS(\mathrm{i})$ (as above) and $D^0(R_i)$. This notation becomes cumbersome when considering analogical topic relations which have been shown to play a crucial part in learning. Since much of this book is devoted to a discussion of analogy relations, I propose to change the notation and to call the graph representing what *may be done to model topic i in a particular independent modelling facility* a behaviour graph *BG*(i), which is simply a more familiar name for a program graph. That is, *BG*(i) determines or advises or recommends *model-building behaviours* (not the behaviours that take place if the model is executed). *TS*(i) will be reserved for the imperative or prescriptive use of *BG*(i), the set of commands or instructions which may be issued when the student receives a demonstration. Similarly, since most conversational domains are necessarily associated with many independent modelling facilities, I shall use the phrase *Lumped Modelling Facility = Set of Independent Modelling Facilities* in place of the terminology employed in the previous monograph namely, "modelling facility", for "Lumped Modelling Facility" and "component of a modelling facility", for "Independent Modelling Facility". In the long run, these changes of notation (not of meaning) are well worth the trouble taken in "translation".

Finally, the conversational domain is described (previous monograph $D^1(R)$) by means of descriptive predicates or *descriptors* which assume particular values on different nodes. The description performs two tasks: (a) It provides an indexing scheme, with meaningful indices, for gaining access to topics in the course of transactions initiated either by the student or the teacher/regulating heuristic. (b) It distinguishes and describes the several universes of interpretation proper to the independent modelling facilities in the Lumped Modelling Facility, i.e., it gives a semantic interpretation both to what may be known and to what may be done (by way of explanatory modelling).

The entailment structure which is displayed to a student thus consists in a mesh (a simplified image of the underlying thesis), its description, and the data links connecting each node for *topic* i to the associated structure *BG*(i). Finally, each node standing for a topic in the entailment structure is provided with electronic storage devices and indicators which display its state. The state depends upon the transactions which have taken place in a strict conversation and the possible states are shown in Table 1.1 (recalled from the previous monograph).

TABLE 1.1
States of Nodes

State	Resulting Transformations
Explore	Gives examples of descriptor values
Aim (validated)	Marks aim topic. Provides display of entailment set and permissible topics
Goal (legal)	Marks topic to be learned about. Permits demonstration and requires non-verbal explanation
Subgoal	Particular goal transactions are monitored
Understood	Determined by operating system and displays student progress

Just as an explanation in the CASTE operating system is a model built in a modelling facility, so a derivation (an explanation of how the explanation was obtained) is modelled as a sequence of state distributions upon the entailment structure. These taken together delineate the learning strategy adopted by the student. As a practical point, it is crucial that the state markers are displayed continually to the student as well as to the regulating heuristic/teacher and an external observer.

The CASTE transactions are shown in Table 1.2 (again recapitulating the previous monograph) together with their status as L statements. One of the transactions in Table 1.2 (aim validation) is novel; the reply to an explore transaction is also augmented by further descriptive data.

The rules for transactions in this operating system are designed to secure an understanding (i.e., the evidence of an explanation and a derivation) for each topic learned. This is the least biassed mode of operation, referred to in the previous monograph as a cognitive reflector. Tutorial arrangements are obtained by embellishing the cognitive reflector; namely, adding constraints to ensure that the student's learning strategy is dominated by an imposed teaching strategy.

TABLE 1.2

Transaction Types (as in the previous monograph)

		Commands	Questions	Executions	Explanations
		Comm^1_A i	EQuest^1_A i	Exec^1_A i (Learning strategy)	Expl^1_A i
	Base	Aim Specification: Student (A) stipulates a desired aim by citing descriptor names and descriptor values sufficient to identify topic node.		Aim Validation: If BOSS testing validates aim, then aim specification becomes Aim, as below. Failing that, student must explore for further information.	
L^1		Aim i	Aim i	Exec^1_B i (EntSet display)	Cooperative Transactions
	Qualified	Explore i	EQuest^1_A ji	Exec^1_A ji (Learning Strategy)	Expl^1_A ji
		Accept aim i	Tagaim i	Exec^1_B i	Cooperative Transactions
	Base	Comm^0_A i	EQuest^0_A i	Exec^0_A i	Expl^0_A i
L^0		Goal ji_kjm_{ki}	Goal ji_kjm_{ki}	Exec^0_B i (Demonstration)	Cooperative Transactions
	Qualified	Comm^0_A ji	EQuest^0_A ji	Exec^0_A ji	Expl^0_A ji
		Subgoal ji	Subgoal ji	Exec^0_B ji (Demonstration)	Cooperative Transactions

2.2. Use of CASTE and Its Field Station Relative INTUITION

In the studies to be described, CASTE has been employed to maintain a minimally biassed conversation; namely, as a cognitive reflector.

In this capacity the equipment exteriorises a strict conversation between a student and a regulating heuristic which could be humanly executed but is normally computer implemented. Whereas, previously, the heuristic was executed by a time shared system based on a PDP10 and interfaced from the modem into a special purpose computer (rather than the terminal normally connected for time sharing), it has proved more convenient to run the heuristic in a computer located in the laboratory. This is a small and inexpensive minimachine with fast operation, an LSI 2 with 16k of store and digital tape cassette backup. The system has two functions.

(a) To secure the understanding condition for each topic said to be learned (and to regulate learning over the entire conversational domain).

(b) To provide cooperative assistance, by way of demonstrations and other help-giving transactions, so that learning is possible. This operation is programmed (in pursuit of minimal bias) to provide as little cooperation as the student needs and, in any case, to record details of the cooperation furnished.

Apart from this, the equipment keeps a record of all transactions and the entire sequence of state marker distributions on the entailment structure.

2.3. Requirement for an Inexpensive Version

Our research has moved towards schools and colleges; most of the current programme of experiments is based upon remotely located field stations. On the one hand, it would be physically difficult to install bulky equipment (CASTE) in a field site. On the other hand, it would be quite undesirable to do so.

The main object of the field research, to investigate conversational methods and principles applied in the context of real educational institutions, depends upon securing cooperation from the teaching staff, and, so far as possible, their active involvement in the ongoing experiments with a view to developing courses and further applications. To work with pieces of equipment that are manifestly too costly to fit an academic budget would defeat the purpose. If the equipment is to be seriously considered, it must be perceived as potentially available as a scholastic tool.

2.4. The INTUITION Operating System

For these reasons, a good deal of effort was devoted to developing an operating system with the main characteristics of CASTE, which has components that are moderately inexpensive and can be readily conceived as items on a budgeting par with laboratory demonstrations. The result of the development is a system called INTUITION, an acronym for "Individual Tuition System".

Any subject matter can be encoded; the most refined course being an appreciable extension of "Probability Theory" (the main example of the previous monograph). However, the encoding, in the interests of inexpensive realisation, leads to prewired modular units called miniature entailment structures, each containing the nodes of 30 or 35 topics. The miniature entailment structures have state markers like CASTE but most of the transactions involve inserting plugs (to determine explore or aim or goal as the case may be) and these operations activate the computing equipment prewired into each modular unit.

The modelling facility, STATLAB II, is more elaborate than STATLAB I (previous monograph). Amongst other things it accommodates many stage experiments, several independent universes (both in the real and abstract worlds), and incorporates the distinct notions of causation, probabilistic causation and correlation, as well as complex conditional probabilities. This component is quite expensive, but it can be seen as a "Statistics laboratory" in toto, and it is not difficult to imagine separate bits of equipment concerned with the different demonstrations and explanatory models that are fabricated in the whole laboratory.

As in CASTE, demonstrations are given with the aid of overlay cards placed on the modelling facility and bearing instructions that tell the student how to build a model. The demonstrations used by a student are registered electrically and listed so as to check for and prohibit mere copying. Explanations are elicited as models and are marked for rectitude and progress by a check and instruction list recorder which also recycles the student according to the outcome.

Descriptive materials are provided, as before, in the form of slides arranged in a random access projector which is centrally controlled and sensitive to explore or aim transactions. Confidence estimates are obtained by a miniature form of BOSS (the Belief

Fig. 1.1. The INTUITION System. Typical working station. A = Entailment structure display (probability theory). B = Node with state marker lamps, sockets, contacts, labels; used in transactions described in the text. C = Screen for display of descriptor examples and counterexamples through random access projector. D = Random access projector. E = Check list device. F = Modelling facility for subject matter or probabilistic theory, STATLAB. G = "Boxes" used for conditional probability experiments. H = Tape recorder for inputting random or quasi random "natural results" together with spoken commentary on the external demonstration. I = Files containing "layover cards" for STATLAB, other demonstration material and aim validation cards for insertion in mini BOSS (not shown in this photograph). J = Control and recording mechanism which may be interfaced with minicomputer for class (not shown in this photograph). K = Student position.

and Opinion Sampling System of the previous monograph). A typical field working station is shown in Fig. 1.1; BOSS in Fig. 1.2.

Together with the recording and control facilities required for experiments, it is quite an elaborate installation. But a great deal of the complexity can be abandoned for teacher monitored tutorial applications (where direct involvement is encouraged) and the

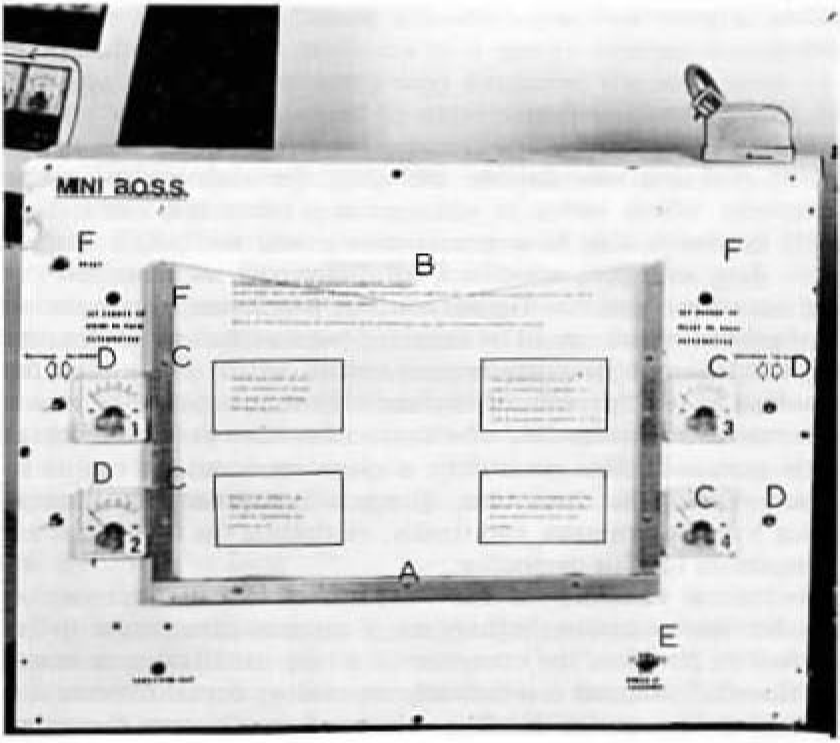

Fig. 1.2. Mini BOSS confidence estimation equipment. A = Card holder (reads punched hole code on the question card inserted and displayed for response elicitation). B = Card inserted. C = Meters showing result of automatic normalisation of response to guarantee that it is a valid confidence estimate. D = Buttons manipulated by student and used to increase and decrease his estimate of belief about "correct" alternative answer to the question. E = Submission button pressed by student if displayed confidence estimate is in agreement with his "correct belief". F = Signal lamps for control of response process.

other components appear as embellishments, necessary only for experimentation.

In order to operate INTUITION, the student must subscribe to a number of "game rules" (about how to put in plugs, what indicator lamps mean, how to instrument the transactions). These rules are stated in Appendix A and seem burdensome. But, learned by experience, they are not hard to comprehend or obey and the system is presented as a "learning game" rather than a tutorial device.

2.5. Discussion of System

With full implementation, including the elaborate recording equipment which serves in addition as a controller, the INTUITION system is able to accommodate nearly all CASTE transactions. Aim and goal selections are differently implemented (by plug insertion), and the Tagaim routine, which searches for understood subordinates, cannot be executed because the logical circuitry of the entailment structure is prewired. However, it is possible for a student to use "explain of explain". That is, suppose he wishes to assert his understanding of a topic other than the primitives (as a side comment, this possibility is quite essential), he can do so by announcing his intention, giving a non-verbal explanation, stating a derivation path, and finally, explaining the topics that are prerequisites for this derivation.

Mechanical checking of the "explain of explain" transaction calls for the computer; otherwise, a manual check must be instituted. In practice, the computer is a very useful adjunct in any experimental run, and it is virtually mandatory for monitoring and supervising the group learning discussed in Chapter 6 (several students with the same entailment structure and a learning strategy consensually selected, or several stduents and duplicated entailment structures so that several learning strategies proper to individuals or subgroups coexist in the system). Apart from sorting out who did what, the computer acts as a device for distributing explanations amongst the members of the group. The algorithm takes advantage of the redundancy which exists in any conjunctive substructure of an entailment structure and its associated *BG*s. That is, if *topic* k is superordinate (in a substructure) to *topic* i and *topic* j then the explanation of *topic* k will involve repeating the explanations of *topic* i and *topic* j and, of course, giving some novel explanation; *BG*k embodies *BG*i and *BG*j together with some fresh exercises.

This redundancy is quite advantageous for the individual learner (though we have a procedure that condenses explanations to reduce their redundancy if it becomes excessive). In a group situation, however, repetition holds up progress and soon becomes intolerable. The algorithm thus distributes parts of the explanation of a topic among the members of a group working together so that: (a) Each member has finally explained the head topic of a substructure, perhaps in part by explaining subordinate topics, before selecting a further head topic. (b) The burden of repetitious explanation is distributed equally amongst the members of the group who are working together.

The criticism (on cost grounds) suggested in Section 2.3 is not too troublesome. The computer is often regarded as part of the recording equipment and it is seen as unnecessary (as, for individual operation, it *is*). If people wish to enquire more deeply into the cost benefit of the system, it can be honestly pointed out that just as the computer programs can supervise a group of students, so also, the same machinery can be used to regulate conversational activity in a class of up to 10 or 11 students, only the inexpensive parts of the hardware being dedicated to students individually.

2.6. *Recording of Data*

All Explore, Aim, Goal, Subgoal, Understood transactions are recorded on digital magnetic tape; so are the check and instruction list transactions and the demonstrations received. The BOSS equipment used in Aim Validation is electrically traced, acceptable correct certainty is determined, and the confidence estimates recorded. Several spare recording inputs are available; these are used in group operation for monitoring the FRIM transactions (which realise IPM like interactions between students) noted in Chapter 6. Key features and states of STATLAB II are recorded to detect crass misuse of the check list facility, and (in a group) recorded segments are prefaced by student identifiers.

2.7. *Some Deficiencies and Their Remedies*

Because of the relatively small size of the miniature entailment structures (Fig. 1.3 is typical), and the method of specifying both the exploration of a topic and the aim topic chosen, students were inclined to trivialise the aim transaction. Faced with the requirement of choosing some aim (as a precondition for goal selection and gaining access to demonstrations), the student may aim for a topic on grounds of layout, paying no obvious attention to the meaning of the descriptions. An aim of this kind is not (in the technical sense) an aim. The student cannot describe the topic for which he is aiming; that is, he cannot locate it in a space of descriptors such as "real/abstract" or "structural/metrical".

This disturbing manifestation was noted initially in the context of sparse exploration prior to aim selection. Consequently, we greatly enriched the exemplary material provided in response to an explore transaction. So far as possible, the enrichment was systematised in the spirit of Nelson's (1974) *hypertext* (Fig. 1.4).

An immediate (and apparently universal) result was a very marked increase (a factor of 5 to 10) in the number of explore transactions. Though gratifying, this result was not enough. For some students, though casting around by explore transactions, still had no pretence of a description of the aim topic (typical comments were, "it's at the top" or "it's the next one up"). We thus introduced a further procedure, Aim Validation, to ensure that before a student is allowed to instate an aim, he can describe the aim topic.

Aim Validation depends upon eliciting confidence estimates using a piece of equipment (Fig. 1.2) which is a scaled down version of the Belief and Opinion Sampling System (BOSS) described in the previous monograph. As in BOSS the student is presented with multiple choice questions (having one and only one "correct" answer). From his response (setting up meter readings that represent his belief that each of the alternatives may be "correct"), it is easy to calculate uncertainties and Shuford Scores. The questioning alternatives are constructed by specifying AltSets and an Alter$^+$ (previous monograph); they are inscribed on cards with electrical designating codes and inserted, as required, in the card reader (Fig. 1.2).

Suppose a student aims for *topic* i. He is questioned by cards that refer to the semantic descriptors of *topic* i. Notice that estimates of "look ahead uncertainty" and "belief" are obtained using question alternatives that refer to the syntactic and derivational coordinates of a topic. Here, the alternatives refer to the *descriptor* used to access, or point at, the topic. So, for example, if *topic* i is described by "material/structural" and by "real/abstract" the alternatives are formulated by citing objects or situations which (depending upon the nature of the topic) fill the cells in an array like:

	Metrical	Not Metrical (structure)
Real		×
Not Real (abstract)		

Suppose *Topic* i is described as structural and real. If so, any alternative set contains one "correct" object or situation (marked x in the array) and the alternative set is produced by citing four alternatives, of which one is "correct" and the others have divergent values of one or the other or both descriptors.

In general, descriptors are many (rather than two) valued so that even for a uniquely described topic, it is necessary to use a series of cards rather than one. To each card the student gives a confidence estimate response and his aim (*topic* i) is deemed valid if his Shuford score exceeds a threshold (conveniently, of 0.8).

If an aim is validated, the student is allowed to instate it. If not

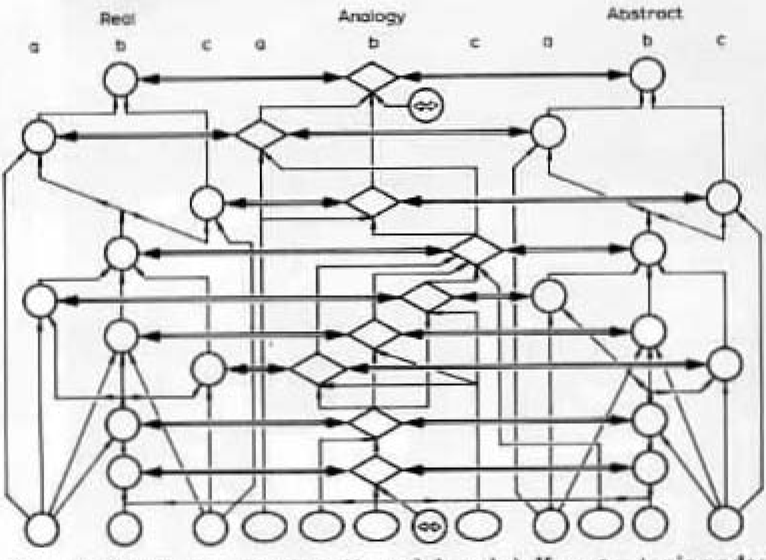

Fig. 1.3. Entailment structure (1 module only). Key: ○ = topic node; ◇ = analogical topic node; line arcs = derivations; double line arcs = analogues.

Fig. 1.4. A typical example and counterexample descriptor value slide.

(score less than the threshold), he is requested to continue explore transactions as a result of which he can gain further information about the meaning of the descriptors. Validation guarantees that the student can, at least, discriminate objects or situations in terms of the descriptors; the descriptors are to that extent meaningful.

The check secures the desired result. If there is only one way of completely describing the topic, then the routine goes on as already outlined. On the other hand, if there are several possible descriptors (redundancy based on many descriptors, all of which specify the topic), it is necessary to construct subsets of alternatives proper to each sufficient subset of descriptor values and to present the student with aim validation questions based upon the particular descriptors he chose to employ.

For INTUITION, where the aim transaction consists in plug insertion (an explore transaction, qualified and interpreted as an aim), there is no way of determining, directly, which descriptors the student actually chose and it is assumed that all are used. As a practical point, the glossing so introduced is not too damaging

Fig. 1.5. Arrangements used in semi-mechanised free-learning and teachback experiments on learning style. A = Back projection unit for displaying examples. B = Selection buttons and signal lamps. C = Auxiliary indexing buttons. D = Confidence estimation equipment for determining look ahead uncertainty or topic uncertainty as numerical values. E = Lower point of the entailment structure (facing student but just visible in photograph).

since the descriptors are usually not very redundant (when they are, the student is asked which subset of descriptors he did employ). In CASTE (where aim validation is currently also implemented), the subset is specified as part of the transaction: for the student points at the topic by dialing a subset of descriptor values (indices) sufficient to uniquely ostend the topic. The aim validation procedure is thus implemented (but in essentially the same manner) with respect to whatever subset of descriptions is cited by a student.

2.8. Other Modifications

Recent work has shown the importance of analogical topic relations in learning. Hence, many of the entailment structures (for almost any subject matter) are replete with analogy relations. As a result the difficulties over modelling analogy (need for comparison of the topics related by the analogy) and the difficulties in accessing an analogy (that the existing routines do not generally allow the student to understand an analogy before the topics it relates) become obtrusive. These difficulties were mentioned in the previous monograph and were not completely surmounted.

In all of the present operating systems, the nodes of analogical topics are distinguished as requiring special accessing routines. These routines are fully implemented, but fairly complex. They can be much more meaningfully described in Chapters 4 and 6 when the characteristics of analogies have been discussed in detail. We thus note the existence of special routines and defer further discussion of them until later.

3. LESS RESTRICTIVE OPERATING SYSTEMS

An operating system (CASTE or INTUITION) secures a standard condition in which students who learn are required to understand each topic. Useful though it is as a standard, the condition is so stringent that it prohibits many interestingly defective methods of learning which deserve investigation. In order to study these (technical) misdemeanours, the standard condition is relaxed in various ways.

3.1. Less Rigid Regulations

Within a mechanised, heuristically regulated operating system, it is possible to systematically and selectively reduce the constraints which ensure understanding (for example, by replacing the requirement for non-verbal explanation with a correct response criteria, the analogue of ineffective as compared with effective teachback). It is also possible to withdraw the cooperative assistance provided either by stripping away part of the entailment structure, distorting the descriptive data (furnished in response to explore transactions) or by a stage by stage impoverishment of the demonstrations. All of these expedients have been adopted with the results described in Chapter 3. Several variations are possible.

3.2. Verbal Methods

On a different tack, the formalised conversational language L may be replaced by a (natural-language-speaking) participant experimenter, substituted for the regulating heuristic. Two variants upon this theme have been employed quite widely. One of the two is a combination of closely monitored free learning (with exploration of an indexed data base, founded on an entailment structure) and subsequent tape recorded teachback. The other is a mechanised form of the same procedure which is useful as a conversational test paradigm. Both methods are illustrated with reference to taxonomy learning but they can be employed for many different tasks.

3.2.1. Monitored Free Learning

Students are briefed about the task and the procedure to be followed. They are shown a graphical display of the indexed data base and examples of the kind of information available from it. No strict time limit is imposed; this is done to prevent undue haste or anxiety in performing the task, factors that might prevent students from exhibiting coherent behaviour. But the experimenter calls a halt to learning after $1-1\frac{1}{2}$ hours work, by which time students have typically settled down to the task and are following a stable learning strategy.

The following cycle of events takes place.

(1) A student states his "aim". Aim statements are typically of the form, "I wish to learn about the official taxonomy based on

the categories A, B, C and D" (index description). Stating an aim does not restrict the student (hence, aim is much less strictly specified than it is in INTUITION). Other categories may be accessed and often are accessed if the student uses redundant or over specified information.

(2) The student requests access to cards in a data file by pointing out its indices (via a dialling arrangement, to allow for recording).

(3) For each card selection the student must state (into a tape recorder) his reason for requesting the card. Further, he must classify his intention under one of the following headings, by pressing selection buttons on his console (Fig. 1.5).

(a) Exploratory search: An intention to explore the categories in terms of the type of information available, without attending to specific content.

(b) General search: An intention to examine the content of cards with no commitment to its being relevant.

(c) Request for a particular item of information. Here the subject is asking a specific question in the form "How many legs does this kind of animal have", or "What distinguishes X animals from Y animals in terms of behavioural habits?"

(d) Requesting several particulars. Here the student is asking a complex question of the form "What are the several features that distinguish X animals from Y animals?" or "How many legs and how many heads has an X animal, and how is this related to the code name?"

(e) Testing a simple hypothesis. Here the student wishes to check a particular belief, for example, that "2" in a suffix refers to the number of heads.

(f) Testing a complex hypothesis. Here the student wishes to check a complex belief, for example, that an X animal has one head, three legs and a bushy tail.

When more than one card is selected, the cards may correspond to different intention classes or several cards may be subsumed under the same intention. In the latter case, the student is allowed access to the several cards simultaneously. Otherwise, cards are accessed one at a time.

(4) First, all the cards selected are moved from the data file to a card holder and arranged singly or in clusters. For each intention, the student takes out and reads the associated card or cards, making notes if he wishes. When finished, he returns the card(s) to

the data file and proceeds to deal with a further card or cluster of cards, repeating the cycle until his card holder is empty. The student is also required to give a commentary into the tape recorder of the results of his actions: whether he has been successful, what notes if any he has taken, and so on.

(5) If, during the cycle, the student wishes to modify his intention or request different cards he may do so, but first the card(s) being examined must be returned to the data file. This arrangement encourages the student to cluster his cards under intentions, veridically. Pilot studies showed that without this restriction a student is tempted to cluster *all* his requested cards together.

(6) When his card holder is empty, the student restates his aim (Step 1) and the cycle of events is repeated.

3.2.2. The Mechanised Procedure for Monitored Free Learning

The mechanised procedure has been used chiefly for learning theses about biological systems, typically using the menstrual cycle as a data base.

Information about the subject matter is partitioned into "chunks" each consisting of approximately 50 words. Each chunk stands alone as a statement but also cross refers to other chunks in which the meaning of terms is explicated.

A set of slides is prepared and used in a piece of equipment (Fig. 1.5) which incorporates a random access projector. Access to a particular slide is obtained by pressing one of 12 keys on a keyboard, whereupon the slide corresponding to the key pressed is projected. If no further key pressing occurs, after 25 seconds the screen goes blank. Key pressing must be repeated if the same slide is still required. Recording equipment records, on punched tape, which slide is requested on each occasion and the interval of its exposure (to the nearest 2.5 secs.).

The student's task is to learn about the menstrual cycle. He is permitted free access to all slides at all times and is given no time limit. He is told merely that the session ends when he feels ready to give a teachback account of what he has learned. The main restriction is that he is not permitted to take notes.

3.2.3. Teachback Method

Both types of free learning are followed by teachback, either "effective" (demanding explanations) or "ineffective" (correct response only, though teachback conditions are closely simulated). As noted earlier "teachback" (described in the previous monograph) is a specialised form of the Piaget/Vygotsky interview.

3.2.4. Main Use of the Methods

These relatively unrestricted conversational modes are chiefly used as discriminators of learning style (Chapter 3), and stylistic predictors are based both on the exploration/learning pattern and the form of teachback protocol subsequently obtained from the student.

For example, with respect to exploration and learning, the prediction is that a serialist will adopt a fairly rigid order of attending to the "chunks" and, further, will have a high frequency of consecutive repetitions of particular chunks within his rigid ordering. Conversely, a holist student will access chunks in a more "scattered" manner and have a low frequency of consecutive repetitions of particular chunks.

With respect to teachback protocols, the prediction is that the teachback of a serialist will follow the chunk ordering he has imposed. It will be as if he were recapitulating the frame ordering of a linear programmed text. Conversely, the teachback of a holist will give an account which has little regard for the original chunking. He will have constructed and organised his own set of richly interconnected chunks.