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ABSTRACT

This study examines quantification of the instructional process through the use of Markov chaining, and by considering the transition probabilities within a framework provided by the taxonomy used, attempts to obtain information about behavior sequences common to all lessons. (Author/DLG)

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INVESTIGATIONS INTO THE INSTRUCTIONAL PROCESS

IV. Teaching as a Stochastic Process

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Investigations into the Instructional Process

IV Teaching as a Stochastic Process

1. Some Basic Concepts

Initially, a brief account will be given of the steps involved in the technique used here to quantify the instructional process. This is done with the object of helping the reader not familiar with this technique to follow the analysis and the interpretation of the results. The present report is a sequel to three previous ones, Koskenniemi & Komulainen (1969) and Komulainen (1970 and 1971) published in this series. The same lesson material is dealt with in all four studies. A modification of Flanders's interaction analysis was employed in the analysis of 25 videotaped lessons (Appendix 1). The study is concerned with the work of a single class-room, which was followed by means of a closed-circuit television system for one school term. The analysis can be regarded as a kind of case study.

The school class will be considered as an indivisible holistic whole, in which the instructional process manifests itself as interaction proceeding in time. Within the framework of a class-room, the instructional process may be considered as a system. The system involves two parties - the teacher and the pupils - interacting in a given environment. The system is always in one out of a number of possible states. The taxonomy employed determines the number and quality of the states. The states defined in terms of interaction taxonomies are exhaustive and mutually exclusive. Then, at any point in time t the system will be in one and only one state. The instructional process means a transition of the system from one state to another as a function of time. The further assumption is made that the successive states of the system are capable of a strong chronological ordering, starting from t0.

The following simplified example is intended to illustrate the state of affairs. The unrealistic assumption will first be introduced that the instructional process consists of no more than two states: either the teacher speaks (1) or a pupil speaks (2). The coder will assess the state of the system every three seconds. On the basis of his observations, the following sequence beginning with t1 could emerge:

1 1 1 2 1 1 2 2 1 1 1 1 1 2 2 1 2 2 1 1 1 1 1 1 2 1 1 1 1 1

The workings of the system can be described by means of an <u>interaction matrix</u> (I):

$$I = \begin{array}{c|cc|} & 1 & 2 \\ \hline 1 & 16 & 5 \\ 2 & 5 & 3 \\ \hline \end{array} = \begin{array}{c|cc|} & 1 & 2 \\ \hline 1 & f_{11} & f_{12} \\ 2 & f_{21} & f_{22} \\ \hline \end{array}$$

Each of the <u>cells</u> of the interaction matrix indicates how many times the system has shifted from the state represented by the <u>row</u> to a state represented by the <u>column</u> in question. These <u>transition frequencies</u> will be denoted by f_{11}, f_{12}, etc.

A <u>transition probability matrix</u> or, simply, <u>transition matrix</u> (P) is obtained from the interaction matrix by dividing the transition frequency in any one cell by the sum frequency of its corresponding row. The transition matrix describes the system in the following fashion:

$$P = \begin{array}{c|cc|} & 1 & 2 \\ \hline 1 & .76 & .24 \\ 2 & .63 & .37 \\ \hline \end{array} = \begin{array}{c|cc|} & 1 & 2 \\ \hline 1 & p_{11} & p_{12} \\ 2 & p_{21} & p_{22} \\ \hline \end{array}$$

In this matrix, p_{12} is the probability with which the system, after reaching state 1, will change into state 2. The diagonal entries p_{11} and p_{22} are called the probabilities of a <u>steady state</u>. The transition matrix has the following three properties:

(1) the matrix must be a <u>square matrix</u> (in the example, it is of <u>order</u> 2 x 2)

(2) the row sums must equal 1.00; and

(3) the range of variation of the elements p is 0 - 1.

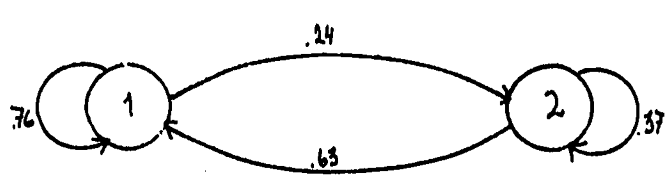
The transition matrix is also called a stochastic matrix.

Situations are met where we have two interaction matrices based on observation periods differing in length. To render the matrices comparable, the transition frequencies may be transformed into percentages of the total number of transitions. The matrix thus obtained is called a <u>percentage matrix</u> (I%):

$$I\% = \begin{array}{c} \\ 1 \\ 2 \end{array} \begin{array}{c} \begin{array}{cc} 1 & 2 \end{array} \\ \begin{bmatrix} 57.0 & 17.2 \\ 17.2 & 18.6 \end{bmatrix} \end{array} = \begin{array}{c} \\ 1 \\ 2 \end{array} \begin{array}{c} \begin{array}{cc} 1 & 2 \end{array} \\ \begin{bmatrix} \%_{11} & \%_{12} \\ \%_{21} & \%_{22} \end{bmatrix} \end{array}$$

By means of the percentage matrix and transition matrix the behaviour of the system can be described, and inferences and predictions concerning it can be made. In previous reports (Koskenniemi & Komulainen 1969 and Komulainen 1971) the entries of the percentage matrix were used as the values of the variables in both P and O type factor analyses.

Employing another mode of description we may say that the instructional process is a process in a <u>graph</u> or <u>network</u>, the <u>points</u> of which represent states of the system, <u>steps</u> on the network representing the possible transitions (i.e., transitions for which the theoretical $p > 0$) from one state to another.



Of the original states of the system (n in number) state combinations can be formed (e.g., transition from one state to another = a new state; n^2 in number), which can be considered as further states of the system in a more thorough analysis. The <u>second-order interaction matrix</u>, for instance, is as follows:

I =

	11	12	21	22
11	11	4		
12			2	3
21	4	1		
22			3	0

=

	11	12	21	22
11	f_{111}	f_{112}		
12			f_{121}	f_{122}
21	f_{211}	f_{212}		
22			f_{221}	f_{222}

The transition frequency f_{121} shows how many times the system has shifted from state 12 to state 21. The empty cells represent instances where direct transition from one state to another is not possible. The empty cells form, by columns and by rows, a systematic pattern. This property will be utilized later in the present work, in the presentation of transition matrices that are larger in size.

The <u>second-order transition matrix</u> of the system is given below.

P =

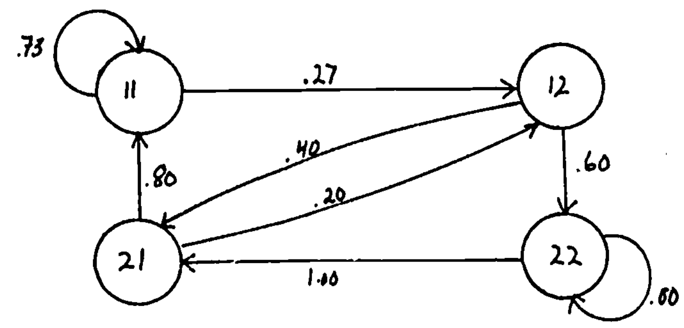
	11	12	21	22
11	.73	.27	0	0
12	0	0	.40	.60
21	.80	.20	0	0
22	0	0	1.00	.00

=

	11	12	21	22
11	p_{111}	p_{112}		
12			p_{121}	p_{122}
21	p_{211}	p_{212}		
22			p_{221}	p_{222}

The probabilities in the second-order transition matrix can be read in two synonymous ways. p_{212} indicates the probability with which the system, after reaching state 21, will shift to state 12; or the probability with which the system, after reaching state 1 via state 2, will shift to state 2. The second-order Markov chain is a stochastic process whose transition probabilities depend on the two preceding states. Thus we observe that the probability vectors of matrix P represent this property of the second-order Markov chain.

When the behaviour of the system is described on a network, the following representation is obtained:



This kind of representation already provides a more differentiated picture of the instructional process. It reveals that the parts played by the teacher and the pupils differ considerably. The amount of information is notably greater here, in comparison with an analysis confined to the consideration of first-order connections alone. There are states between which no two-way connections exist; and there are states not connected at all with other states by a single step. Nevertheless, multistep roundabout connections exist between any two states. An example is provided by state 22: a direct transition from it to state 11 is impossible, but state 11 can be reached, e.g., via state 21.

From the taxonomy employed here it follows that the first-order states of the system number 13 and the second-order states $13^2 = 169$. It goes without saying that, with such a large amount of information, economy of its analysis is a highly important consideration.

The literature drawn on in this chapter includes: Kemeny & Snell (1962), Bartos (1967), Svalastoga (1959), Lipschutz (1968), Feller (1968) and Busacker & Saaty (1965).

2. The Instructional Process as a Markov Chain

A Markov chain is a stochastic process where the future of the system depends exclusively on its present state and not on the past phases of the process or on the way its present state was arrived at (Feller 1968, 444). The second-order Markov chain is a stochastic process in which the transition probability of the system depends, at any particular moment, on its present state and the immediately preceding state but not on any more extensive developmental context. The instructional process is, no doubt, largely a time-dependent process, i.e., a stochastic process whose transition probabilities change systematically as a function of time. However, no mathematical models allowing for both of these properties are available.

In the present study Markov chains will only be used to describe the instructional process. An attempt will be made, by considering the transition probabilities and within a framework provided by the taxonomy used, to obtain information about behaviour sequences common to all lessons. On the other hand, preliminary knowledge of this sort can be used as a model, or as a kind of null hypothesis, in setting out to acquire more material or in investigating situations where either the subject matter or the composition of the body of pupils is different. The assumption that successive states are completely independent can be rejected. Pena found (1968, 27-33) that a second-order Markov chain gave a significantly better description of interaction (i.e., better fit) than a first-order chain. She tested the fit in the way suggested by Hoel, the null hypothesis being that the first- and second-order transition probabilities do not differ significantly (Hoel 1954, 430-433). Also, certain ethological investigations have revealed that the predictability of interaction between animals increases rather sharply when lower-order chains are replaced by higher-order chains. The situation in human interaction is likely to be more complicated. With animals - in Altman's (1962) studies, with rhesus monkeys -

behaviour at the interactional level is more stereotyped, as a result of the more limited short-term memory of animals and because animal bahaviour is guided to a large extent by biologically-based factors. During the instructional process, a dependence on previous states may be brought about by more holistic factors; and, on the other hand, the degree of this dependence varies during the process. An effect is of course also contributed by the fact that here the behaviour of the system is co-determined not only by its past but also by the goal intended to be achieved. Goals differ in their degree of distinctness, and this can hardly fail to structure the course of the instructional process and render it dependent to varying extents.

Flanders has, together with Darwin, considered matrices as first-order Markov chains. Their goal was not, however, description but an overall comparison of two matrices (Darwin 1959, 412-419).

The second-order Markov chain is very suitable for use in the analysis of the general characteristics of the instructional process common to various lessons. A sequence can be described by following the route of the highest probability. The stimulus value of any given state may be investigated by indentifying the states whose probabilities of occurrence are enhanced by it. The merits of the model include exactitude and mathematical clarity: transition probabilities have a clear interpretational meaning. As for its drawbacks, it should be pointed out that it is not at all easy to find a general index for the lengthy sequences obtained (cf. the factor score). Moreover, a 169 x 13 matrix is so large in size (2 197 cells) that a great deal of material must be available in order that the invariant characteristics could be brought in relief. Therefore, in this study, only a single matrix was computed from all the lessons. The number of transitions (about 14 000) thus became sufficiently large.

3. Results

The results are presented here in such a way that the large matrix is partitioned into smaller units. The information about category Z will be omitted, since instances assigned to it were very rare and its theoretical significance is also slight. Each of the rows of the matrix represents the possibilities of transition to a third state after given two states. The absolute frequencies corresponding to the rows are given in column N. These frequencies varied widely. Particular caution is called for where the frequency in a row is less than 30: the p values corresponding to such rows are very sensitive to chance factors. Where a cell is empty, this means that the combination concerned never occurred. Where $p = .00$, this means that the probability is less than .005. If the sum for a row does not equal unity, this is due either to rounding or to the omission of the Z category. The tables are arranged in such a way that the middlemost category is the same in each case. Thus, the entry in the first cell on the left in the topmost row of Table 1 means that the probability of transition from state (1-1) to state (1-1), or in symbols, p_{111} equals .18.

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 1	.18	.14	.09	.27	.05	.09			.05	.05		.09	22
2 - 1			1.00										1
3 - 1				.50						.50			2
4a - 1				.14		.29		.14		.43			7
4b - 1							.50		.50				2
5 - 1	.11	.11	.11			.22	.22		.11			.11	9
6 - 1								.50	.50				2
7 - 1				1.00									1
8 - 1	.02	.00	.29	.18	.05	.17	.07	.03	.07	.05	.00	.06	614
9a - 1	.02	.01	.21	.05	.03	.29	.08	.04	.02	.15	.02	.10	198
9b - 1					.09	.45		.09		.09	.09	.09	11
10 - 1			.09	.09			.36	.09	.27			.09	11

Table 1. Transition probabilities $p_{.1.}$.

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	
1 - 2		.29		.14		.14			.29	.14			7
2 - 2		.28		.08		.18	.10		.10	.20		.08	40
3 - 2													0
4a- 2		1.00											1
4b- 2					1.00								1
5 - 2		.20		.07		.53			.07	.07		.07	15
6 - 2		1.00											1
7 - 2		.33				.67							3
8 - 2	.01	.11		.17	.02	.17	.07	.01	.34	.01	.01	.06	82
9a- 2		.15		.11		.21	.20	.02	.03	.11	.03	.15	66
9b- 2				.50		.30			.10			.10	10
10 - 2		.33				.33	.17					.17	6

Table 2. Transition probabilities $p_{.2.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 3			.63	.05	.02	.16	.00	.01	.04	.03	.01	.04	226
2 - 3													0
3 - 3			.46	.07	.01	.23	.01	.01	.02	.11	.01	.06	303
4a- 3													0
4b- 3													0
5 - 3			1.00										1
6 - 3				1.00									2
7 - 3			1.00										1
8 - 3	.06		.56	.06		.22			.06		.06		18
9a- 3	.06		.50	.06	.06	.06	.06	.06		.06		.06	16
9b- 3													0
10 - 3			1.00										1

Table 3. Transition probabilities $p_{.3.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	
1 - 4a	.02			.10		.02	.03	.01	.49	.01	.02	.31	130
2 - 4a				.06		.06	.06	.03	.52	.03		.23	31
3 - 4a				.22		.05			.30			.43	37
4a- 4a	.01			.25	.01	.02	.02	.04	.27	.01	.01	.35	137
4b- 4a						.50			.50				2
5 - 4a	.01			.18	.00	.04	.06	.02	.37	.01	.01	.24	225
6 - 4a				.02		.08	.16	.02	.43	.06		.24	51
7 - 4a				.17		.08		.17	.38	.04	.04	.08	24
8 - 4a	.01			.08		.02	.07	.02	.60	.02		.17	96
9a- 4a				.05					.47	.26		.21	19
9b- 4a				.20		.20		.20	.20			.20	5
10 - 4a	.01	.01		.13		.02	.01	.04	.27	.03	.01	.47	146

Table 4. Transition probabilities $p_{.4a.}$.

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 4b	.03	.03			.33	.08			.28	.03		.23	39
2 - 4b					.67				.33				3
3 - 4b	.10				.20				.50			.20	10
4a- 4b					.50				.50				2
4b- 4b				.01	.32	.01	.01	.01	.37			.27	79
5 - 4b				.02	.36	.02	.05	.02	.30	.02		.21	56
6 - 4b					.44				.22	.11		.22	9
7 - 4b					.40				.20			.40	5
8 - 4b					.08		.08		.33			.50	12
9a- 4b												1.00	1
9b- 4b													0
10 - 4b					.50		.06		.33	.06		.06	18

Table 5. Transition probabilities $p_{.4b.}$.

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 5				.08	.01	.68	.03	.03	.05	.06		.05	173
2 - 5				.10	.02	.57	.04	.04	.06	.10		.08	51
3 - 5				.06	.01	.85	.01	.02		.04		.02	113
4a- 5	.03	.09		.09		.50	.09		.09	.03		.06	34
4b- 5					.40	.40						.20	5
5 - 5	.00	.00	.00	.06	.02	.78	.02	.01	.01	.05	.01	.04	2615
6 - 5		.01		.03	.01	.58	.16	.03	.03	.01		.12	73
7 - 5				.08	.03	.66	.05	.06	.02	.03		.06	62
8 - 5	.02	.02		.15	.02	.53	.04		.13	.02		.06	47
9a- 5	.02	.01		.04		.41	.11	.03	.04	.17	.02	.14	169
9b- 5				.12		.41	.12	.06			.12	.12	17
10 - 5	.00	.00		.10		.57	.07	.02	.04	.03	.01	.14	207

Table 6. Transition probabilities $p_{.5.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 6			.03	.05		.11	.23	.02	.22	.09		.22	65
2 - 6						.17	.25	.04	.17	.08		.25	24
3 - 6				.20		.20	.40					.20	5
4a- 6				.25	.03	.03	.18	.05	.18		.03	.28	40
4b- 6					.50	.33						.17	6
5 - 6				.07	.01	.07	.34	.02	.15	.05	.01	.22	123
6 - 6		.00		.03	.01	.07	.47	.03	.05	.07	.01	.18	390
7 - 6				.02		.06	.27	.06	.21	.06	.02	.25	52
8 - 6	.01			.06		.03	.20	.07	.43	.06		.12	86
9a- 6				.05		.12	.41	.03	.07	.12		.15	59
9b- 6	.13			.13			.25	.13			.38		8
10 - 6				.05	.01	.05	.36	.03	.12	.08		.29	154

Table 7. Transition probabilities $p_{.6.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 7			.04	.04		.21	.07	.43	.07	.04	.04	.07	28
2 - 7									.50	.50			2
3 - 7						.29		.43		.14		.14	7
4a- 7				.12	.04	.08	.12	.35	.12	.08		.12	26
4b- 7								1.00					2
5 - 7		.02		.05		.18	.03	.38	.03	.06		.20	65
6 - 7				.03		.03	.22	.42	.08		.06	.14	36
7 - 7		.01		.04	.01	.05	.07	.43	.05	.06	.02	.23	256
8 - 7	.04			.04		.09	.04	.39	.26			.13	23
9a- 7				.07		.20	.07	.27	.07	.07		.17	30
9b- 7				.07		.10	.10	.21	.03		.07	.38	29
10 - 7					.01	.10	.10	.38	.04	.07	.03	.28	120

Table 8. Transition probabilities $p_{.7.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 8	.52	.03	.03	.03	.03	.03	.02		.29				58
2 - 8	.39	.11		.05		.03	.03		.37			.03	38
3 - 8	.67								.27			.07	15
4a- 8	.43	.05	.01	.12	.00	.05	.07	.03	.16	.02	.01	.04	356
4b- 8	.65	.01	.01	.01	.01	.01	.03		.26				77
5 - 8	.44	.11	.04	.04	.02	.05	.04		.25			.02	55
6 - 8	.14	.05		.05		.02	.05	.01	.62		.01	.05	133
7 - 8	.28	.05	.03	.03			.05		.49		.03	.03	39
8 - 8	.14	.02	.00	.02	.00	.01	.03	.01	.72	.00	.00	.05	1293
9a- 8	.50	.17							.33				6
9b- 8		.20		.20			.20		.40				5
10 - 8	.37	.04	.01	.04	.01	.01	.04	.01	.40	.01		.08	339

Table 9. Transition probabilities $p_{.8.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 9a	.30	.10	.05			.18	.05			.25		.07	60
2 - 9a	.17	.22				.28	.06	.11		.11		.06	18
3 - 9a	.23	.03	.03	.05		.15		.03		.48		.03	40
4a- 9a	.13	.04		.04		.48	.09		.09	.09		.04	23
4b- 9a	.25	.25				.25				.25			4
5 - 9a	.22	.08	.02	.02		.26	.04	.03		.29		.06	192
6 - 9a	.17	.04		.06		.23	.16	.09		.13		.13	70
7 - 9a	.22	.11		.03		.14	.11	.19		.11		.06	36
8 - 9a	.13			.06		.44	.06	.06	.13	.06		.06	16
9a- 9b	.29	.06	.03	.01	.00	.09	.02	.01	.00	.42	.00	.06	241
9b- 9a	.50					.50							2
10 - 9a	.17	.09	.01	.03		.21	.14	.02	.01	.20	.01	.10	150

Table 10. Transition probabilities $p_{.9a.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	N
1 - 9b		.50				.33	.17						6
2 - 9b				.33				.67					3
3 - 9b	.14							.14			.57	.14	7
4a- 9b		.13					.13		.13	.13	.25	.25	8
4b- 9b													0
5 - 9b	.13	.04				.17	.04	.33			.13	.17	24
6 - 9b						.27	.09	.18	.09			.36	11
7 - 9b		.23		.08			.15	.23			.23	.08	13
8 - 9b				.13				.13	.38		.25	.13	8
9a- 9b	.33									.33		.33	3
9b- 9b	.15	.04		.04				.15			.35	.27	26
10 - 9b	.06	.03		.03		.22	.06	.19			.14	.25	36

Table 11. Transition probabilities $p_{.9b.}$

	1	2	3	4a	4b	5	6	7	8	9a	9b	10	
1 - 10			.02	.16		.23	.05	.07	.03	.11	.02	.31	61
2 - 10		.05				.24	.14						21
3 - 10				.07	.03	.45	.07	.07	.03	.24		.03	29
4a- 10	.01			.10	.00	.04	.03	.03	.45	.02	.01	.30	284
4b- 10				.04	.07			.02	.72	.02		.14	57
5 - 10	.01	.01		.06	.02	.27	.05	.04	.06	.11		.38	193
6 - 10	.00			.07	.00	.07	.15	.06	.10	.08	.04	.44	210
7 - 10				.09	.01	.10	.05	.15	.06	.09	.01	.45	136
8 - 10	.04	.01		.03	.01	.04	.05	.04	.62	.04		.14	111
9a- 10		.02		.02		.05	.05	.02	.02	.27	.02	.54	59
9b- 10				.03		.10	.03	.03	.03	.03	.16	.58	31
10 - 10	.00	.00		.05	.05	.05	.06	.04	.04	.04	.01	.69	1342

Table 12. Transition probabilities $p_{.10.}$

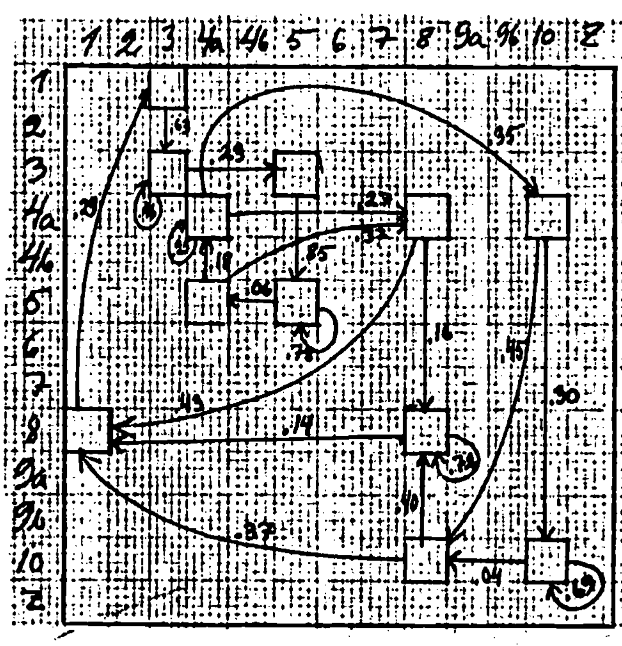


Figure 1. A circuit sequence (starting from 5-5 and ending in 5-5)

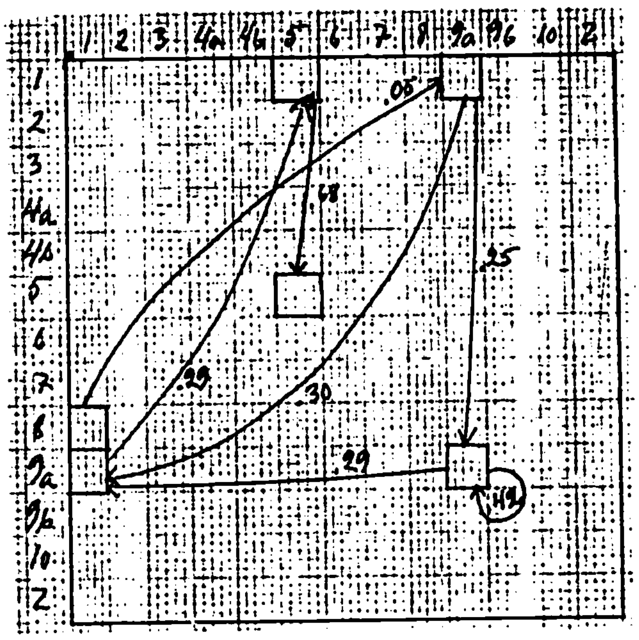


Figure 2. A condensation sequence (starting from 8 - 1 and ending in 5-5)

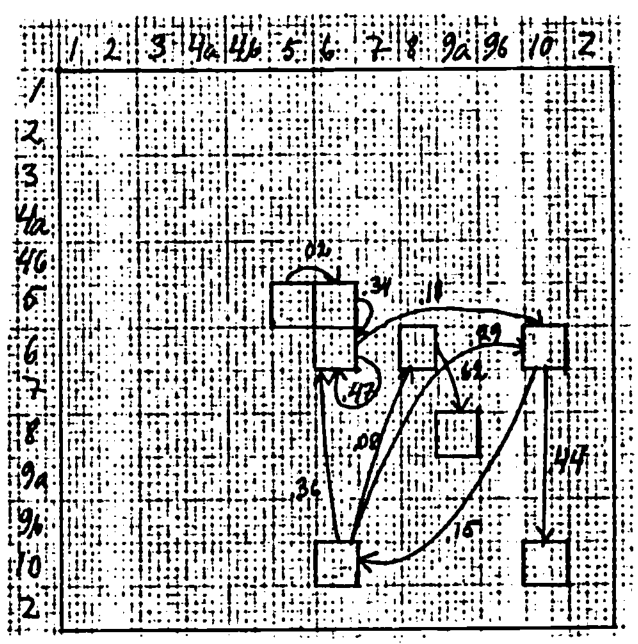


Figure 3. A condensation sequence (starting from 5-5 and ending either in 10-10 or in 8-8)

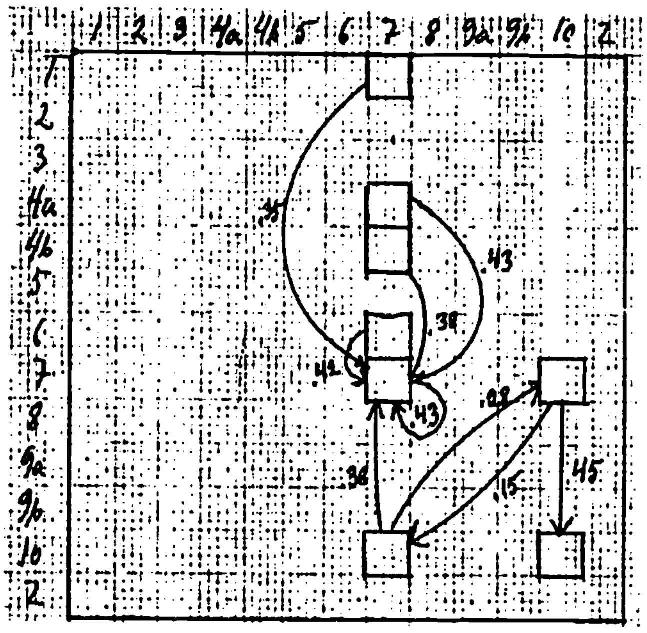


Figure 4. A condensation sequence (starting from almost any state related to column 7 and leading via 7-7 to 10-10)

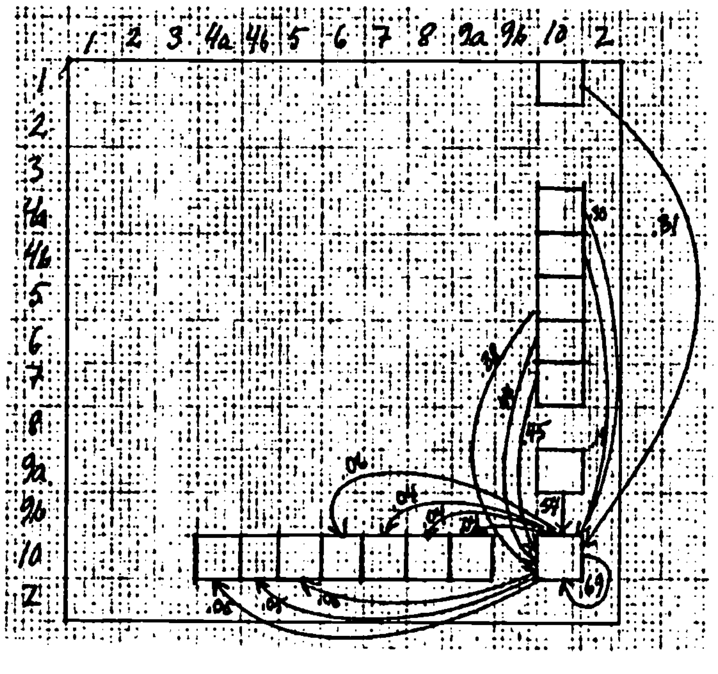


Figure 5. The position of category 10-10 as a kind of crossroads or as a transitional state

The sequences singled out here for consideration furnish supplementary information for the interpretation of the sequences obtained by factor analytical means (Komulainen 1971). In the present material the sequences are classifiable into two principal types. A good example of the first type is provided by the sequence represented in Figure 1, which both starts from and ends in state 5-5. Typical of such a circuit sequence is a high probability of recurrence. In the instructional process, sequences of this kind from a constant, recurrent element that is predictable with a comparatively high degree of accuracy. Condensation-type sequences are represented in Figures 2, 3 and 4. The beginning of such a sequence cannot be predicted. When the system has reached, for one reason or another, a state that is favourable for such a sequence to start, it will behave for some time in a lawful fashion. And when the sequence has been completed numerous alternative courses are open. None of these differs definitely from the rest in probability. Condensation sequences are very often associated with disturbances in the instructional process. The criticism sequence represented in Figure 4 is a case in point. When the system has reached a state, for some reason or other, that involves criticism, there is a high probability for it to proceed to state 7-7, and a sequence represented in the figure is likely to ensue. The system is then likely to attain state 10-10, from which a number of equally probable alternative routes lead ahead. Figure 5, again, represents one typical cell where a number of various routes cross. Here, too, none of the routes leading ahead clearly differs from the others.

4. Critical Observations on Flanders-type Interaction Analysis

Certain difficulties, limiting their use and the generalization of the results obtained by them, are generally associated with observation methods. However, each observation method also has special problems of its own, and its further development depends on how far these problems can be solved. In each particular study, the experience gained in previous studies should be taken into account, so that the methodological foundation on which the study rests would be as well-developed as possible, both theoretically and technically. Mainly the following points are open to criticism:

(1) The method is suited only to teaching situations where the group of pupils acts as an undifferentiated system under the direction of the teacher. Only in such situations will interaction form a meaningful, unambiguously describable series of events - which is a precondition for, e.g., the use of Markov chains. Where the instructional process divides into two or more comparatively independent subsystems, each of which seeks to achieve its own special aims within the framework of a common, more comprehensive goal, interaction analysis loses its effectiveness. The picture obtained by means of interaction analysis of the instructional system will then become wholly misleading.

(2) A fact related to what was stated above is that a Flanders-type method only records interaction within an instructional system in the vertical direction (teacher - pupil). When the system works as an undifferentiated whole (frontal instruction), horizontal interaction occurs, however, in the group of pupils. This important aspect is ignored by Flanders's interaction technique almost completely. The only exception is provided by cases where a pupil's speech is immediately

followed by another pupil's speech, without the teacher's intervening (coding: ...8-8-8-10-8-8...). A natural subsystem is formed in frontal teaching situations, too, by pupils sitting near to one another in the class-room. When a shy pupil urges his more courageous companion to ask the teacher a question concerning a point that has remained obscure, the subsystem affects the main system, and the event will be coded. Nevertheless, the process through which the question came into being remains outside the main system and will not be coded. A further important research task is comparison of various instructional groupings and various forms of teaching. Such comparative analysis is not, however, feasible by means of the methods available. Commensurability is not attainable in the comparative analysis of various forms of teaching. As I see it, this fact is particularly important from the standpoint of the models of the instructional process - and of greater import than is the problem of subject-specificity. The social form of the instructional process decisively affects the number of necessary models.

(3) In a certain respect the interaction-type approach has led to an impasse. If we seek to analyse a phenomenon in greater detail, the number of categories is bound to increase; the number of cells in the interaction matrix will then increase as the second power of the number of categories, and the number of combinations of second-order Markov chains will increase as its third power. The relevant matrices will then be too thin for ordinary research purposes (the mathematical expectation per cell approaching zero). Hundreds and thousands of lessons will be necessary if we wish to find any regular patterns. On the other hand, if we are content with a small number of categories, the method will be marred by ipsativeness and, often, by excessive simplicity: no investigation

would have been necessary for us to know the result. Everybody has been familiar in advance with the fact that, if the teacher asks a question, it is highly probable that one pupil or another will answer. A knowledge more detailed than this about the didactic process is of course expected from a researcher. One noteworthy solution model is provided by multi-dimensional parallel codings (e.g., Bellack & Kliebard 1966 and Winnefeld 1957). It should be mentioned at this point that in the analysis of the didactic process that is under way at the University of Helsinki Institute of Education (the present study forming part of this project), three different taxonomies - namely, those of Bales, Bellack and Flanders - have been applied to the same situations, each in a slightly modified form.

(4) Even where interaction schemes are outwardly similar, their contents and cognitive structure may vary widely, both quantitatively and qualitatively. The communication of information in interaction is not easy to map out (cf. the criticisms made by Ausubel of B. O. Smith; Ausubel 1967).

(5) The use of a non-symmetric taxonomy (i.e., different systems of description for the parties concerned) has the consequence that the manners of influencing of the parties of interaction cannot be compared, since they have been measured differently. The classification concerning pupils, which is not sufficiently differentiated, requires improvement.

5. Continuation of the Study

In Autumn, 1969, after a research period of two years, the pupils of our laboratory class passed to grammar school and their intensive observation came to an end. The same autumn another group of subjects (20 pupils of the third grade) entered our laboratory school, which they are going to attend for two years. This two-year period will terminate this year. The writer intends to carry out analyses similar to the present ones on the basis of the material secured during these two years. Use will be made thereby of the information already acquired about these pupils by means of extensive individual and group testings and by means of interviews. The results of the analysis will be published in this report series.

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Appendix 1.

The Employed Classification System

Teacher talk	1 .	Accepts, praises or encourages
	2 .	Corrective feedback
	3 .	Uses pupil ideas
	4a.	Asks narrow questions
	4b.	Asks broad questions
	5 .	Expresses information or own opinions
	6 .	Gives directions
	7 .	Criticizes pupil behaviour
Pupil talk	8 .	Answers to a question
	9a.	Relevant spontaneous talk and suggestions
	9b.	Irrelevant spontaneous talk
Others	10 .	Silent work, individual work or guidance
	Z .	Tumult, confused situation

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