Systematic Classroom Analysis Notation

For Mathematics Lessons

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SCAN - a Systematic Classroom Analysis Notation for mathematics lessons

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SCAN allows an observer to record live the essence of the dialogue in a mathematics lesson and to relate it to content, teacher objectives, pupil work and the use of resources. It works simultaneously on three time scales - the Event, the Episode and the Activity. This information is potentially useful in curriculum development, teacher training and classroom research. The system and its preliminary testing are described with illustrations.

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1 Introduction

In this paper we describe a method of recording in detail some of the essentials of a mathematics lesson. We leave to Section 5 a discussion of possible applications, but there is need for an effective system of this sort. Our original motivation was to provide feed-back in the development of curriculum material, in particular the teaching units of the ITMA Project[1], which is exploring the use of the microcomputer as a teaching aid. We have found that SCAN provides a framework for much more detailed, even quantitative communication about a lesson than emerges from conventional, unstructured impressions. It shapes the awareness of both teachers and observers.

Any such attempt must be a balance between the amount of information acquired and economy of effort. We have sought to develop a technique suitable for a single observer, who with a modest amount of training and no equipment beyond pencil and paper, is able to obtain the record while the lesson takes place. The record can also be supplimented with samples of curriculum material and pupil work and a brief discussion with the teacher on the aims of the lesson and how it went. The constraints necessarily restrict the amount of information that can be obtained; we regard them as necessary if the scheme is to provide a useful practical tool for the systematic improvement of curriculum materials. The SCAN record is not, of course, an end in itself; the observer must be able to draw from it the inferences appropriate to its particular application. We do assume that the observer is a mathematics teacher; indeed we regard the limited range of dialogue conventions of mathematics teaching as crucial in our ability to record in "real-time", so familiarity is important. For research purposes audio or video-recordings, with full transcripts, yield more detailed information but the cost is high in time, money, loss of flexibility and distortion of the teaching pattern. We believe that SCAN is cost effective in providing useful detailed information about mathematics lessons. It is easy to learn to use from video-tapes and the interested reader may want to try so that he can better judge for himself; such tapes are available at the Shell Centre.

Most of the many observation schemes that have been developed are concerned with the social or other affactive variables of the classroom.

Of the handful that have concerned themselves with intellectual transactions in science teaching, only one has been concerned with mathematics; growing out of the work of Muriel Wright [2] this scheme is, like most of the others, based on "time-slicing", recording the occurrences of various types of event in successive intervals. We started with such an approach, based on a development of the Science Teaching Observation Schedule (STOS) [3], but found that although MaTOS yielded interesting results it did not give the detailed picture of the dialogue that we wanted. We decided, therefore, to look for a scheme based on "natural units of activity". After watching many hours of video-taped mathematics teaching with a fairly "innocent eye", we have developed the SCAN structure.

In section 2 we outline the essence of a simple version of SCAN, with interpretations of several sample records, in order to provide a concrete basis for discussions of its development, testing and applications in sections 3, 4 and 5. Appendix I gives examples of the classification scheme for teacher questions, while Appendix II contains a comparative discussion of SCAN records of four lessons taught with the aid of computer program teaching units, including some illustrative inferences about the program and teaching styles. Appendix III gives a specification and discussion of the full current SCAN-1M version of the system. A fuller discussion of some aspects of this work and its background is available in Reference 4.

SCAN has been largely based on the teaching of John Pain, Paddy Turpitt, Jill Morris, John Godwood and George Knights; we are grateful for all their help and want to record our pleasure in the quality and our good fortune in the variety of their teaching. We have benefited from the reactions of many people to SCAN at various stages but particularly from the comments and ideas of Colin Wells and Alan Bell. We have leaned heavily throughout on the broad shoulders of Jim Eggleston - he educated our naïvete with kindness and encouraged us through our difficulties with his exuberant vital good sense; Judith Rowlands has shown great patience with our many revisions, which include suggestions by Geoffrey Howson and David Johnson.

Table I | SCAN CODE SHEET (SIMPLIFIED VERSION) | SCAN OM

RESOURCES	ACTIVITY LEVEL	EPISODE LEVEL	LINGUISTIC DESCRIPTORS OF EVENTS	EVENT LEVEL QUALIFIERS
TM - teacher produced material PMB - printed material (books) PMC - printed material (cards) C - computer OHP - overhead projector BB - blackboard etc.	E - Exposition, teacher to group of 5 or more D - Dialogue, teacher to group of 5 W_n - Pupil work in groups of n PP - Pupil-pupil dialogue	D - Defining I - Initiating activity CO - Coaching E - Explaining (new material) R - Revising SS - Searching (successful) SU - Searching (unsuccessful) F - Facilitating	g - gambit m - managerial ch - checking question q - question e - explanation, includes definitions a - assertion x - giving example i - instruction, initiation cf - confirmation r - rejection k - correction o - observation (silent) ∧ - repeat remark __FATE OF QUESTIONS__ (q) ✓ - correctly answered x - answer incorrect o - no pupil response	Prefix p for pupils, except in PP dialogue when prefix t for teacher event. __Nature of activity or depth of event__ α - recall, single fact, single act, no processing involved β - exercise of straight-forward nature, putting together several facts or acts γ - extension of previous work involving new ideas __Situation or level of guidance__ 1 - highly structured, close direction, small number of choices. 2 - some guidance, requires connection rather than selection 3 - minimum guidance, open

2 The essence of SCAN

In this Section we outline the simple version of SCAN OM which is summarised in Table I; a much fuller discussion, including the extended version SCAN 1M is given at the end of the paper in Appendix III. We begin with an example of a SCAN record of a small section of a lesson in which the class is working individually (W1) with work cards (PMC); the dialogue (D) between the teacher and individual pupils is recorded as a series of events (separated by /) comprising episodes (//). The event/ $q\alpha 1 \checkmark$ / of the first line below, for example, denotes a teacher question (q) of simple recall (α) where the teacher's guidance is such that the pupil recognises there are only a few alternative possibilities (1) and answers correctly(✓).

LESSON IDENTIFICATION : C

Resources Used	Activity	Events/Episode Summaries	
PMC	W1 →	o/cf/ch/iα2//co pch/eβ1/qα1✓/eα1//co	1
		pch/cf/iα1/iα1/e/pa/cf//co pq/eα1//co	2
		pq/e//co i//co ch/qβ20/qβ1✓	3
		qβ20/λ✓//co o/cf//CH/i//I m//F	4

The dialogue described in the first two lines was the following - we hope that as we describe the system you will be able to follow its illustration on this brief example.

Teacher: / / Yes, that's nice/ o/cf
but what does it mean? What is it?

Pupil 1: I plot this against this./ ch

T: What are you going to write? A title,
The most important thing about any sort
of chart is a title.// iα2 // co

Pupil 2: Do I have to write that down
like that?/ pch

T: You've already got it like that in
base 5. Now you've got to write it down
as an ordinary number,/ eβ1
so how many stars have you got?

P2: I've got 13./ qα1✓

T: So that's what you write down. That's
in base 10.// eα1 // co

Pupil 3: Is this right? Is that how you
do it?/ pch

T: That's right. That's right./ cf

P3: And um,...

T: Three - draw stars for the following
numbers. 9. That's right./ iα1
Now change these two into base 5
numbers, by putting ..

P3: I just put nine little crosses?/ iα1

T: Yes - you split it into a five and
however many are left over./ e

P3: And I divide that into four lots of
five and one, two, ... four./ pa

T: That's right.// cf // co

Pupil 4: I don't see what it means here.
It says "Take 9 in base 10". What does
that mean?/ pq

T: That means that 9 is already in base 10, and you've got to draw nine stars.

P4: Oh, is that all I've got to do?// ed1 || CO

SCAN describes the lesson in terms of three different levels of action on three different time-scales - "event", "episode" and "activity". The descriptions that follow are not meant to be precise definitions, which we regard as unobtainable, but aim to convey a feeling for what we have in mind. (The objectivity of the scheme rests partly on inter-observer consistency but, particularly, on the quality of the "read-back" of a SCAN record when compared with a recording of a lesson; we return to this in section 4).

A lesson is divided into a series of activities. Teacher exposition to the whole class (E) may alternate with pupils working alone (W_1), with teacher/pupil dialogue (D) and some pupil/pupil (PP) dialogues; alternatively, a lesson with work cards may consist entirely of dialogues, and so on.. The activity changes are readily recognisable, by the observer.

Each activity consists of a series of episodes. The labels in Table I are sufficiently self-explanatory for the moment. The boundaries between episodes are usually clear - the teacher moves to talk to another pupil, or from revising previous material to initiating work by the class that will, it is hoped, lead them to the next stage of understanding. Sometimes, however, observers will apply two descriptions to an episode without identifying the point of change. In the example above, the episodes are almost all coaching episodes (CO).

The essence of the SCAN system is in the event level analysis. Event descriptions have some at least of the following elements appearing in this order - you may note them in the example above.

i. The initiator is assumed to be the teacher unless labelled; p indicates that the event is initiated by an unspecified pupil, while a number 1, 2, 3 .... identifies the pupil on a sketched seating plan, written in the resources column at the left of the record sheet, allowing comparison with later events or pupil work.

ii. Linguistic descriptors from the list shown in Table I identify the nature of the event; we sub-divide some of the categories in this simple classification later. Questions of content q, or for checking ch, explanations e including definitions, examples x, and instructions i cause little difficulty; silent observation o, confirmation cf, correction k, and rejection r are equally clear. Other intellectual events are assertions a. Interested as we are in the intellectual transactions, we simply divide the rest into managerial events m and gambits g, which include all facilitations, social or sociable comments. $\wedge$ indicates a repeat of the previous event.

In case of doubt the linguistic role of an event is that perceived by the pupil; we recognise that this statement begs a lot of deep questions about pupil understanding of language, but SCAN does not pretend to work at those depths and we find that in most situations problems do not arise. Note, for example, that rhetorical questions are assertions or explanations, while interrogative statements are questions.

We now suggest that you turn back to the dialogue from the lesson C, and see if you agree with the linguistic classifications given.

An important feature of SCAN is the set of qualifiers, which evaluate the depth of demand that the event makes on the pupil, and the guidance that it provides in helping him to respond to that demand.

iii. The depth of demand on the pupil is described on a three point scale, on the following basis.

α - the recall of a single fact or act,

β - the stringing together of several facts or acts, as in exercises or constructive definitions.

γ - an extension of previous skill or understanding as in discovery or in the solving of a problem with an element of novelty.

iv. The level of guidance

1 - maximum guidance - highly structured so that it is clear to the pupil that only a few possible choices exist.

2 - the essential nature of the demand is clear but the range of possiblities is wider and connection, rather than mere selection, is required.

3 - minimum guidance - the range of possibilities is left as open as possible.

The meaning of the qualifiers will depend on context and experience. Clearly the interpretation of the guidance level depends to some extent on the depth of demand - a simple factual recall cannot be as "open" as a new discovery (though the latter can be almost as closely guided as the former!). Indeed, we wondered for some time whether $\alpha 3$ events could exist, but found a use for this qualifier combination. We illustrate each of the nine categories in Appendix I. Here we only stress that to qualify events accurately requires a knowledge of the background and current competence of the class - even

"Tell me some transformations"

is a question(!) which could be γ or α depending on context. Nonetheless, you may find it worth noting the qualifiers used in the dialogue of lesson C, given above.

v. The response, usually to a question, may be correct ✓, wrong x, or absent o.

In addition, the SCAN record may contain informal notes of several kinds. We find it valuable to record the actual wording of all γ - questions, and of unusual events of all kinds. Notes on the content being covered in each activity may be valuable. A full SCAN record should always be supplemented by information, collected before and after the lesson, on teacher objectives and reactions, the resources used, and samples of pupil work. On occasion interviews with some pupils may be of value.

In practice we find it possible to make SCAN records with somewhat different degrees of detail - for example, a lengthy explanation might be more subtly divided into parts at different levels of demand or guidance. This is but one illustration of the partly personal nature of SCAN - it is a tool that can be used by the individual in the way that he finds most useful for recording aspects of the lesson that seem to him essential.

We shall now illustrate the use of SCAN by giving some examples of SCAN records of lessons and "reading-back" some of what they contain. We deliberately omit from the records all the associated information just mentioned in order to show clearly what is in the SCAN record itself. All these SCAN's are "live" versions made directly from a running video-tape and not "considered" ones made allowing replays of difficult sections. (We give a considered version of the opening of lesson A1 in section 4 for comparison.) We start with a fairly detailed account of the complete lesson A1 before going on to make some comments on what it shows about the style of teacher A; it may be worth noting that this read-back was written by one of us who had not seen the video-tape of the lesson concerned, but whose comments are substantially accurate.

"The lesson opens. The opening exposition of the lesson starts with a revision episode with the teacher at the blackboard posing questions. A straightforward question on the topic is satisfactorily answered. A more searching point is then raised resulting in some correct responses but also an apparent lack of connected thought from some of the class. The teacher returns to the gentle persuasion of the α question/answer technique, interrupting this procedure with two clear assertions of fact. The episode ends with a successful response to an extending γ-question - probably this last question is leading directly towards the exercise about to be tackled by the pupils. The next episode brings a change of direction with teacher alerting the class to their task by a simple factual explanation and instruction - a very short episode which may have not got through to those who did not listen at the start of the lesson. The new activity has pupils working on the exercise (line 3). In a quick return to teacher exposition a higher level instruction to start an exercise is checked by a factual question, leading to another instruction and the return to individual work (line 5).

LESSON IDENTIFICATION : A1 TB

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Events/Episode Summaries</th><th></th></tr>
<tr><td>BB</td><td>E</td><td>qα2✓|qβ1✓|^x|^✓|^o|qα2✓|qβ1✓|qα2✓|</td><td>1</td></tr>
<tr><td></td><td></td><td>a|qα2o|a|qβ1✓|^✓|qγ1✓||R m|d|iα1||I</td><td>2</td></tr>
<tr><td></td><td>W1</td><td>m</td><td>3</td></tr>
<tr><td></td><td>E</td><td>iβ1|qα1✓|iβ1....||I</td><td>4</td></tr>
<tr><td></td><td>W1 D</td><td>g|ch|ch|k|qα1x|iα1✓|qα1✓|c||CO</td><td>5</td></tr>
<tr><td></td><td></td><td>c||CO eα1|k||CO o|| pch|c||CO</td><td>6</td></tr>
<tr><td></td><td></td><td>o|k|qα1...||CO c|ch✓||CH</td><td>7</td></tr>
<tr><td></td><td>E</td><td>m|k|qβ1...|qβ2...|iβ2|pa|m||I</td><td>8</td></tr>
<tr><td></td><td>W5 D</td><td>c|e||CO qβ2|....|qβ2....</td><td>9</td></tr>
<tr><td></td><td></td><td>PP(? ||) qβ3✓|^...|qβ1o||</td><td>10</td></tr>
<tr><td></td><td></td><td>k|...||CO qβ3||SU inaudible</td><td>11</td></tr>
<tr><td></td><td></td><td>q|qβ3|| PP(ch|a|ch|a...||CH</td><td>12</td></tr>
<tr><td></td><td></td><td>ch|a|| ch...|| ch|k|...|a||)</td><td>13</td></tr>
<tr><td></td><td></td><td>q|...|o|| PP(ch|a...|| ch|a||</td><td>14</td></tr>
</table>

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Events/Episode Summaries</th><th></th></tr>
<tr><td></td><td></td><td>ch | k || · k ||) qβ3 PP(.. .)</td><td>15</td></tr>
<tr><td></td><td>E</td><td>m | ch | qβ2✓ | qα1✓ | qβ1✓ | ∧x | qα1✓ |</td><td>16</td></tr>
<tr><td></td><td></td><td>qα1 | ∧o✓ | ch | a || S5</td><td>17</td></tr>
</table>

The dialogue begins with a coaching episode. The teacher's conversational gambit, perhaps having noticed an incorrect procedure, leads to checking questions and a correction. An unsuccessfully answered question is followed by an instruction for clarification and the teacher strengthens futher the pupil's understanding with a successful simple factual question followed by a confirmation, ending the episode. (How many other individuals are in trouble?) The teacher continues around the class and, in a series of fairly short contacts, is learning about the success rate. The next exposition (line 8) suggests that the teacher has spotted a general point of confusion; this is clarified by calling the class's attention, a correction is made leading to "hanging" questions and an instruction at exercise level. A pupil assertion indicates that a further exercise has now been floated for those already completing the first problem posed.

The record now shows groups of 5 pupils in dialogue with the teacher.

After a short coaching episode, helpful questions are left for consideration. A pupil-pupil discussion is not captured by the record. In the following episode not much can be noted but it is clear that the teacher is coaching mainly through questions, some of which remain hanging, with a few direct corrections. It does not appear to be too successful. A pupil-pupil discussion involves checking-up and correcting among themselves. In the final exposition (line 16), the teacher again addresses the class, checking with a straightforward question/answer routine to bring the class together and round off the lesson.

All-in-all a fairly typical maths lesson. The teacher appears to want the pupils to "have a go" and is not tempted to "do it all for them" but is concerned to check fairly quickly on the success rates."

SCAN, as its shorthand nature implies, contains more detail than the read-back; the following comments on style should therefore be compared with the SCAN record itself, rather than the read-back. The revision episode of the opening exposition is conducted almost entirely by question and answer, mainly at explicit exercise (β) level ending with an extension question which a pupil answers. A very simple piece of work is given and quickly done by the class, followed by a well defined exercise, whose description is punctuated by a factual question to bring out an important point. The second work activity consists mainly of checking and coaching of a variety of types - there are more or less explicit instructions. The further short exposition clears the confusion and sets another piece of work which is coached almost entirely by level questions that are left of the pupil to think about. The pupil-pupil dialogue observed was a checking of answers. Quantitatively the number of $\alpha/\beta/\gamma$ questions in the exposition is 12/18/1, with only 4 each of explanations and instructions. The first coaching activity is very detailed and is conducted entirely at the α level while in the second one much less support is given. The concluding exposition seeks to wrap up the topic at a very explicit level with no hanging questions or extensions to suggest a sequel.

LESSON IDENTIFICATION : B

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Event/Episode Summaries</th><th></th></tr>
<tr><td>PMB</td><td>E</td><td>m | qα2o | d | qα2✓ | x | d | qα1 | qα2✓✓ |
R₁</td><td>1</td></tr>
<tr><td>BB</td><td></td><td>qα1o✓ | qα3o | qα2✓ | d | qα1✓✓✓ | qα2✓ |
R₂</td><td>2</td></tr>
<tr><td></td><td></td><td>qα1✓ | qα1✓ | qα1✓ | aα1 | qα3o | qα2✓ | qα1o |</td><td>3</td></tr>
<tr><td></td><td></td><td>d | nα1 | qα1✓ | aα1 || D d | qα1o∧✓ | d |</td><td>4</td></tr>
<tr><td></td><td></td><td>a | d | iα1 | iα1 | i | e | qα1 | a | iγ3 || I</td><td>5</td></tr>
<tr><td></td><td>W1 D</td><td>o | o || PP (1ch | 2e || CH) c || C PP(ch |
R₁</td><td>6</td></tr>
<tr><td></td><td></td><td>c || CH) m || M PP (ch | ch || CH) k || CH</td><td>7</td></tr>
<tr><td></td><td></td><td>o | k || CH k || CH k || CH pq | inaudible.</td><td>8</td></tr>
</table>

Lesson C: continued

<table>
<tr><td>PMC</td><td>W1 D</td><td>pch | eβ2 | qα1✓ | eα1 || CO pq | c || CO</td><td>5</td></tr>
<tr><td></td><td></td><td>pq | o | k || CO pa | qβ2✓ || CO m ||</td><td>6</td></tr>
<tr><td></td><td></td><td>pa | i || pch | eα1 | pqβ2 | iβ2... || CO</td><td>7</td></tr>
<tr><td></td><td></td><td>k | qβ1✓ | qβ1✓ | qβ1✓ | qβ1✓ | c || CO</td><td>8</td></tr>
<tr><td></td><td></td><td>pq | k | iβ1.... || CO pch | k | qβ2x✓ |</td><td>9</td></tr>
<tr><td></td><td></td><td>iα1 | eβ2 | pq | qα1 | iα1 || CO m ||</td><td>10</td></tr>
</table>

Some readers may feel that this is so typical that all mathematics teaching is more or less in this style. We now, therefore, give a shorter extract from the opening of a lesson by Teacher B and we also give the continuation of lesson C which provided the opening example in this section. We shall not here give a step-by-step read-back for each of these SCAN's, hoping the reader has by now got some feeling for the notation, but only point to some of the clear stylistic differences. It is, of course, self evident that such brief extracts as we have given can only suggest some essentials of a teacher's style which may vary with the material and the age and ability of the class. More records are needed for each teacher to provide reliable evidence, though there is some evidence to suggest that we do not vary our style as much as we might suppose!

First the obvious - Teacher C uses work cards (PMC) and this individualised or group learning means that the lesson is entirely dialogue, mainly coaching episodes; A and B, using blackboard and textbook respectively, alternate exposition with dialogue. Teacher A breaks up the initiation of pupil activity into three separate short expositions.

Looking a little more deeply, let us compare the demand and guidance levels typical of these lessons. It is notable that the opening exposition in B is entirely by question and answer at the α level, apart from the startling i γ 3 at the very end. This,with the general close guidance provided, leads to a lot of successful responses from individual pupils to the teacher's questions. Lesson A1 works much more at the β 1 level, explicitly demanding more extended responses - though the punctuation of α - questions brings out important points. The overall balance of the dialogue is illustrated by Table II which gives the incidence of different events in the complete lesson.

The pupil initiation of events is frequent in C, whose coaching episodes show many interesting features. They are more extended than those in the dialogues of A1 and B, while the even balance and rhythm of successful questions, explanations and final instructions mainly at β level, contrasts with the mainly corrective approach in B and the

Lesson		A1	B	C
Questions asked (resolved)	α	12(5)	19(12)	7(3)
	β	18(6)	7(1)	14(9)
	γ	1(1)	0	0
explanation		3	12	12
assertions/ instructions		11	9	13
pupil questions		1	3	12
pupil explanations		1	1	3

Table II

extensive use of the hanging final question in A1.

In none of these lessons is there any significant extension (γ) activity.

We have, so far, confined ourselves to a fairly broad look at teaching styles though SCAN seems to allow for greater precision of description. It also encourages a study of the characteristic rhythms of a teacher's style with a possibility of tuning them to increase their effectiveness.

We give a few examples of the sort of question that might be raised on the basis of the records of A1, B and C; they are also relevant to those discussed in Appendix II.

> How does the question and answer technique of exposition compare with direct explanation?
>
> For how many pupils is the closing γ- question effective?
>
> In general, is the correct response to γ- questions understood by all or most pupils around or should a teacher explanation at β - level be added?
>
> Does an opening exposition at α1-level produce total pupil understanding, as a basis for the work activity initiated?

If a lower level episode is terminated by a $\gamma 3$ question or instruction, how many pupils make the conceptual leap involved and is the role of the extension made clear later?

In individualised learning, given the very short time allowed for each coaching episode, how far are they effective in maintaining useful pupil activity?

How does pupil activity depend on the level of demand and guidance? (note the balance - an $i\alpha 1$ is usually easy to follow, but quickly exhausted, while an $i\beta 2$ (let alone an $i\gamma 3$) may well be abortive for some pupils).

Now the cynic might well ask "But how has SCAN enabled you to ask such questions? Would not any skilled observer have raised them?" We find in practice that SCAN provides a disciplined structure for observing that leads to much clearer impressions of both the detailed form and general balance of the lesson, and raises such questions as these in more explicit terms. The basic language promotes fuller and easier communication between observer and teacher. Other members of the curriculum team get explicit feed-back in a compact form which provides the framework for discussions on the future development of the material used - the common alternatives are unstructured impressions, for which it is hard to judge their proper importance, and full audio or video recordings which absorb too much time and energy for regular use in curriculum development. As with any language, the structure of SCAN focuses attention on the concepts which it emphasises, particularly the levels of demand and guidance, and the rhythm of the dialogue. It allows quantitative measures of the relative importance of effects that the informal observer must choose either to emphasise or ignore. We find that experience with SCAN heightens the awareness of teachers and observers of their teaching styles and the range of possibilities open to them.

The SCAN record suggests questions like those above in explicit terms; to answer them, of course, needs further information on teaching objectives and pupil work outcomes.

3 The development of SCAN

We shall now return to the process of development that has led to the current version of SCAN in order to make clear the choices that were made and the motivation for them, and to allow the reader to consider other possibilities.

SCAN grew directly out of a wish for more systematic feed-back in the development of curriculum materials. The project "Investigations of Teaching with Microcomputers as an Aid" (ITMA), directed by one of us (RF), is developing educational computer programs to help teachers in various subjects, including mathematics. The approach aims to ensure that the microcomputer is a teaching aid in the classroom, helping to make the teacher more effective and certainly not replacing him, as Computer Assisted Learning so often does. To do this we need a way of observing the teacher in action, both without and with the microcomputer resource. We will then have evidence to help the teacher decide if he likes the effect of the resource on his teaching, and to suggest modifications to improve the program, or his use of it.

This may seem to some an excessively elaborate, even pedantic, approach to curriculum development. We shall return to discuss the general question in Section 5. Here we merely point out the explosive effect of putting a teaching microcomputer into the classroom. It is a highly compelling, even addictive device, that can easily monopolise the children's attention. We need to be sure that what happens in the classroom is really advancing the educational objectives; for example, that too much time is not being absorbed in the trivial aspects of interacting with the computer, and that the intellectual activities that occur are at the level that the teacher wants. We shall discuss elsewhere the various dimensions in the design and use of teaching programs; here we are concerned simply to point out the value of a method of recording some of the essentials of what goes on.

As raw material for developing a design for an observation system, we made video-tapes of three mathematics teachers from the ITMA team doing two lessons each and recorded a further seven lessons in which they use a microcomputer with certain specific teaching programs Happily, the teachers gave us a variety of quite distinct styles. The basic raw material was recorded by the Media Services Unit at the College of St. Mark and St. John; we are most grateful to its Director, David Jones, and his staff for their help and tolerance. Most of the sessions were recorded in the studio (with 15 children rather than 30), but in the case of one teacher, who uses a resource based learning system, we went into the classroom with mobile equipment. We are, of course, concerned about the inevitable distortions of normal classroom patterns that either approach produces; our impression, in accord with others' experience, is that after a short settling-in period the pattern of <u>intellectual</u> transactions is not essentially altered; this is our central concern. The social climate is certainly distorted with very few remarks of the "I do like your hairstyle" type recorded.

In summary, we were satisfied that the mathematics lessons with conventional resources that we recorded were an adequate basis for beginning the development of an observation procedure. It was clear that the lessons with a microcomputer were not more than an indication of possibilities and pitfalls, since the teachers were not acclimatised to the medium or to the programs being used, which were mostly still in draft form. Nonetheless, we have learnt a lot from these recordings as well.

In attempting the design of a system of detailed feed-back (we should like to use the word micro-evaluation, but dislike its air of finality), we look first at some existing schemes of observation. The only ones we found that were specifically designed for mathematics lessons, the Wright system [2] and variants of it, seem to require perceptions by the observer of the child's learning processes deeper than we were willing to contemplate, and also seemed to record too little detail of the dialogue itself. We ourselves developed a mathematics version of the Science Teaching Observation Schedule (STOS) of Eggleston, Galton and Jones[3] with the aid of the first author, from whose advice and comment we have continually benefitted; we call it MaTOS. We found this straightforward to use on video-taped lessons but the three-minute timeslices it uses gives information relevant to a more strategic analysis of the lesson than was our main concern.

We then decided simply to look at a good deal of mathematics teaching, initially on video-tape, with as an "innocent" eye as possible, searching for what we regarded as significant natural units of activity. We were quite clear that the most important processes, those taking place in the pupils' minds, were largely inaccessible to the observer in the classroom. The teaching, principally by the teacher but also by fellow pupils, which an individual pupil receives is, almost by definition, observable; it is this that the teacher can in principle alter and improve and it is on this teaching that we decided to concentrate. After much discussion and development, the result is the SCAN system outlined in Section 2, and described in more detail later. We will describe the rationale behind its main features, in the context of our testing them in the next Section.

The development of SCAN is by no means over. As we use it, we regularly find additional aspects of a mathematics lesson which we should like to record, and devise more or less personal notations to do so - although it is an intrinsic feature of the SCAN system that notes by the observer on particularly interesting points run alongside the SCAN record. We plan to include various specific improvements - for example a timing indicator will be added, based on signals from an electronic device that gives a "bleep" in the observer's ear at one minute intervals. However, we have found the central approach to be robust and in no need of serious modification. We have no strong views on the question of objectivity in the SCAN code - on the one hand we regard it as a shorthand which simply allows the observer to reconstruct a much more detailed and reliable picture of the lesson being watched for an immediate analysis of its important features; on the other hand, we have found it extremely valuable to be able to talk to others in the language of SCAN and to make detailed references to particular SCAN records and for this a generally accepted code is useful. The situation is somewhat analogous to the choice of units in scientific measurement or calculation - for a particular purpose there will often be a convenient system of units which would be quite inappropriate in other situations but a standard system helps communication.

Apart from its possible applications which we discuss in Section 5, we shall not spend long looking at probable future developments of SCAN, though we see a number of hopeful avenues. We conclude on a cautionary note - the extension of the notation to other subjects is a substantial challenge; as we have already said, we believe that the ability to record mathematics teaching as it happens depends strongly on the limited range of remarks that are characteristic of teaching that subject. The teaching of science, or modern languages, though presenting technical problems with much in common to those we have faced, probably involves some quite new factors. We look forward to examining this problem with our colleagues in other subjects but plan to do so "ab initio", taking another long innocent look at teaching dialogue.

4 Testing SCAN

We shall now discuss the criteria which we should like an observation system to satisfy and describe how we have assessed the performance of SCAN relative to them. High inter-observer reliability (i.e. consistency) indicates some objective basis for any system and it is certainly important if SCAN is to be more than a personal shorthand - and it may be measured. However, it is too easy to over-emphasise such "objective measures" at the expense of evidence of the validity or usefulness of the system, which is much harder to test. In our case we are aiming to get a concise record of the mathematics lesson that contains the essential information on its effectiveness that is needed to improve either the performance of the teacher or the materials being used in the lesson. We thus place great importance on the "read-back" of the lesson from the SCAN record and drawing inferences from it; it is, of course, harder to provide quantitative measures of these. Finally, we should like to test SCAN fully embedded in the context for which it was developed, since the system is a tool and not an end in itself; we have made only preliminary and informal attempts at this so far; since each of these applications demands further development work before it can be properly assessed.

a) The testing of interobserver consistency demands the specification of three elements,

i) the system to be tested
ii) the measures of consistency to be used
iii) the training programme for the observers.

So far, we have done only simple testing. The system is the SCAN system, either in its OM or 1M versions. Minimal formal training of observers has been used - in some cases the observations were made as part of an introduction to SCAN, immediately after our standard short description of the system which is illustrated by video-tape and takes about one hour. Some comparisons have been made between SCANs by two more experienced observers, namely two of the authors, based both on video-tapes of lessons and on live lessons; even here no training programme aimed at establishing consistency has been attempted, so the numbers should be taken as lower limits on what can be acheived. Even so, we believe that they are generally satisfactory, for the practical purposes of interpretation by their authors, at least. The choice of measures is a difficult, and necessarily partly arbitrary one. On the one hand we could assess the probability that the two event sequences being compared were quite uncorrelated; in this way we should get most impressive numerical support for our system. On the other, we could penalise every deviation between the two records including for example, regarding their getting out-of-step a lethal non-correlation. In practice we adopt measures related to the latter, much harsher, criterion but with modifications to allow for various types and amounts of acceptable imprecision. In particular

a) We do not mind if some events are divided, i.e. counted twice by an observer; we therefore, in comparing two records, identify the events that are the same and thus keep the records in step. Typically only about two-thirds of the events are recorded by both of the observers.

b) The linguistic descriptors are important - we do not want imprecision here except in so far as SCAN - OM lumps together descriptors that are discriminated in the 1M version. In two live lessons S and T the linguistic descriptors agreed in 82% and 79% of the events recorded by both observers - this is typical.

c) The qualifiers are of great importance but high precision does not matter in displaying the essential rhythms of the teacher dialogues which we seek to record; some latitude in either dimension (α, β, γ or 1, 2, 3) can be allowed. In practice we find an error of one unit in about half the events for each variable. More precisely we have:

	mean of squares of differences in	
	depth qualifiers	guidance qualifiers
Lesson T	.44	.55
Lesson S	.37	.66

We shall define a selection of overall measures, each of which gives a percentage of events where the two observers "agree". We distinguish between the number N_E of events with exact agreement, where all descriptors are the same, and the number N_N of near agreements, where a difference of the linguistic descriptor or of one unit in either of the qualifiers is accepted. We similarly distinguish two different total numbers of events - the absolute total T_A of events recorded by either observer, and the total matched events T_B recorded by both observers. We illustrate these definitions with an example. Suppose two observers, 1 and 2, record the following sequences, where we have matched the corresponding events.

Observers		Totals		Agreement	
I	2	A either	B both	E exact	N near
m	m	A	B	E	N
$e\beta 1$	$e\beta 2$	A	B	-	N
$q\alpha 1 \checkmark$	$q\alpha 1 \checkmark$	A	B	E	N
$e\alpha 2$	$e\beta 1$	A	B	-	-
$e\beta 2$	-	A	-	-	-
ch	ch	A	B	E	N
-	a	A	-	-	-
$i\alpha 1$	$i\beta 1$	A	B	-	N
$i\beta 2$	-	A	-	-	-
m	m	A	B	E	N

$T_A = 10$ $T_B = 7$ $N_E = 4$ $N_N = 6$

The events contributing to each number are shown in the appropriate column with their totals at the bottom. We can then define four percentage measures of agreement

$$P_{EA} = 100.\frac{N_E}{T_A} \qquad P_{EB} = 100.\frac{N_E}{T_B} \qquad P_{NA} = 100.\frac{N_N}{T_A}$$

$$P_{NB} = 100.\frac{N_N}{T_B}$$

which in this illustration take the values

$P_{EA} = 40 \qquad P_{EB} = 57 \qquad P_{NA} = 60 \qquad P_{NB} = 86$

The writers have engaged, in pairs, in the following interobserver comparisons:

Q - ¼ hour segment of lesson taught by student teacher.

R - ¼ hour segment of video-taped lesson taught by a teacher in the ITMA project team.

S - a 50 minute lesson taught to bright fourth year pupils by another experienced teacher.

T - a second 50 minute session with same class and teacher as in S.

The following results were obtained.

Comparison	Q	R	S	T
P_{EA}	29	30	29	31
P_{EB}	45	45	49	50
P_{NA}	50	45	41	43
P_{NB}	81	66	70	70

These results are typical of those found in a variety of circumstances. For example, following a brief one and a half hours introduction and training session, nine members of the ITMA project team produced SCANs of a ten minute expository segment of a video-taped lesson, to be matched with a carefully prepared SCAN made by one of the writers. The SCANs are given in full in Table III, the overall measures of agreement are

Teacher	A	B	C	D	E	F	G	H	I
P_{EA}	29	45	63	16	42	37	42	34	47
P_{EB}	42	66	82	42	58	61	61	47	71
P_{NA}	48	52	71	20	52	44	50	50	44
P_{NB}	70	76	91	53	71	72	72	69	84

Although the lesson segment(from lesson B on page 14) contained fairly straightforward questions and explanations they were delivered quite quickly so that the results obtained by some of the teachers are most impressive for such a short training period.

Since three descriptions are usually involved in describing each remark, we regard the agreement as quite satisfactory. Table III shows that the rhythm of the dialogue is very similar in records at this level. As an example of a more varied lesson segment, in Table IV we match a second observer's "live" SCAN of the lesson A1 with the SCAN studied in detail in Section 2; we suggest that the pictures of teaching style that emerge from the two accounts are closely similar

However, we point out again that SCAN records are not absolute by showing an example of a carefully considered SCAN of the opening of lesson A1, in which the dialogue including some abortive asides, is more closely analysed. Comparison of Table V with Table IV shows that the differences can be quite important.

Table III Training SCANs of the opening of lesson B

W	A	B	C	D	E	F	G	H	I
m qα3o dα1 qα2✓ x dα2 qα1✓ qα2o✓ qα1∧✓ qα3✓ qα2✓ dα1 qα2✓✓ qα2o∧✓ qα2o eα1 qβ2✓ eα1 qα1✓ eα1 qα3o qα2✓ qα2o dα1 qα1✓ dα1	m qα1o dα1 qα1✓ qα1✓✓ qβ2 qα1✓ i qα2o qα1 eα1 qα1✓ qα1 eα1 qα1x ∧✓ e	m qβ2 dβ1 qα1✓ qα1✓ qα1x✓ qβ1✓ qβ1✓ dα1✓ qβ1✓✓✓ qβ1✓✓ qα2 eα1 qβ1✓ dα1 qα2✓ eα1 qα1 qα2 eα1 qα1✓ eα1	m qα1o eα1 qα1✓ eα1 qα1✓ qα1o✓ qα1✓✓ qα1o qα2✓ eα1 qα1✓✓✓ qα2✓ qα2✓ eα1 qβ1✓ dα1 qα1✓ dα1 qβ1✓ qα1x dα1 qα1✓ dα1	m qα1o e qα1✓ e qα1✓ qα1✓✓ ∧✓ q?3 qα1✓ e qα1✓✓ qα1o∧✓ qα1✓ d qα1✓ d qα1✓ qα1✓ ∧✓ e qα2✓ d.	m qα1o i qα1✓ d qα1✓ qα1✓✓ x∧✓ qα1✓ d qα2✓✓ qα1o∧✓ ∧✓ dα1 qα2✓ dα1 qα1✓ dα1 qα2✓ qα1o dα1 qα1✓ eα1	m qα1✓ eα1 qα1 eα1 qα1✓ ∧✓x qγ1✓ eα1 qα1✓✓ qα1✓ qα1✓ eα1 qα2✓ eα2 qγ1 eα1 qα1 (dα2)✓ eα1 qα1✓ eα1	m qα1x qα2✓ a qα1✓✓ ∧✓ o qα1✓ dα1 qα2✓✓✓ qα2✓ qα1✓ eα qα1✓ eα1 qα1✓ eα1 qβ1✓ qα1o eα1 qα1✓ eα1	m q?3 qα1✓ qα1✓ ∧✓ qα1✓ eα1 qγ3✓✓ eα1 qα1✓ eα1 qα1✓ eα1 qα1✓ qα3 qα1o eα1 qα1✓	m qα3o qα1✓ a qα1✓ qα2✓✓ ∧✓ qα1✓ eα1 qα1✓✓✓ eα1 qβ2✓ eα1 qα2✓ eα1 qα3✓ ∧✓ eα1 eα2 qα1✓ eα2
D	R	R	RD	R	R	IR	RD	R	R
dα1 qα1o∧✓ dα1 dα1 dα1 dα1 eβ1 qα1✓ eβ1 iγ1	eα1 qα1 eα1 m	eα2 qα1o✓ eα1 iα1 iα2 eβ2 qα1✓ eβ1 iα2	dα1 qα2o∧✓ dα1 iα1 eβ1 qα1✓ eβ1 iβ2	qα2✓ d d i qα1✓	d qα1 dα1 m qα1✓ iβ2	eα1 qα1o∧✓ eα1 m eα1 qα1✓ eα1 m	qα1o∧✓ eα1 m dα1 dα1 qα2 e i	qα1o∧✓ m eα qα1 m	eα2 qα1o∧✓ eα2 eα1 eα1 eα2 — qα1✓ eα1 eα1
I	I	I	DI	I	I	I	I	I	I

Table IV Comparison of "live" SCANS of opening section of lesson A1

A	B	A	B
BB	—	ch	ch
E	E	ch	ch
qα2✓	qβ2✓	k	ch
qβ1✓	qβ2o	qα1x	ch
∧x	o	iα1✓	iα1
∧✓	qα2✓	qα1✓	∧
∧o	—	c	c
qα2✓	qβ2✓	CO	CO
qβ1✓	qβ1✓	c	iβ1✓
qα2✓	qβ2✓	CO	CO
a	a	eα1	eβ2
qα2o	qβ2x	k	qα1o
a	a	co	co
qβ1✓	qβ2✓	o	—
∧✓	qβ2✓	pch	pq
qγ1✓	e	e	iβ1✓
R	R	co	co
m	m	o	o
d	x	k	k
—	eβ1	—	eα1
iα1	iβ1	qα1...	qβ1o
I	I	co	co
W1	W1	c	c
m	m	ch✓	qα1✓
E	—	—	c
iβ1	iβ1	CH	CH
qα1✓	qα1✓	E	E
iβ1...	iβ1	—	g
—	iβ1	m	m
I	I	k	eβ1
W1	W1	—	m
D	D	qβ1...	iβ1
g	g	qβ2...	∧

$P_{EA} = 46$

$P_{EB} = 67$

$P_{NA} = 55$

$P_{NB} = 80$

Table V "Considered" SCAN of opening of lesson A1

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Event/Episode Summary</th></tr>
<tr><td>BB</td><td>E</td><td>what does about a point mean?
qα3✓ (R) | qβ1✓ k̂ (qγ3 • h (qα1✓) hr) ∧ o |</td></tr>
<tr><td></td><td></td><td>qα3 ✓ (qβ1✓)...✓ ∧ o (eα1 | qβ1×✓) |</td></tr>
<tr><td></td><td></td><td>is one different ?
qγ1✓ | eβ1 | m (R) | dβ1 | eα1 | iα1 || R,I</td></tr>
<tr><td></td><td>W1</td><td>m | m ||</td></tr>
<tr><td></td><td>E</td><td>m (R) | iβ1 | qα1✓ | eβ1 | iβ2 | eβ2 | iβ2 || I</td></tr>
<tr><td></td><td>W1 D</td><td>g | qα3o | qα1o | eα1 | qα1× | iα1 | c | qα1✓ |</td></tr>
<tr><td></td><td></td><td>c || co   c || C   eβ1 | k || co</td></tr>
<tr><td></td><td></td><td>o | ? | o || ?   pqα1 | eα1 || co   p? | k | eβ1 |</td></tr>
<tr><td></td><td></td><td>iβ1 || I   c | ch | c || C</td></tr>
</table>

Now let us turn to the less formal, more qualitative evidence which has lead us to believe that the information contained in the SCAN record is of value. It is largely unstructured and we shall discuss ways in which more objective measures of the features described might be sought in the future.

b) Read-back

We have some experience of descriptions of lessons based purely on the SCAN record by observers who have not seen the lesson. It was the first of these (by RF) and the subsequent comparisons of the description with the video-tape of the lesson (which suggested that there was little to add to the read-back account) that provided early encouragement in this work. In general we find that what we regard as the important aspects of the teaching style are clearly recorded together with the nature of the pupils' responses to it. However, good quantitative measures would be hard to devise - checklists could be produced but may not easily give the right balance of weight between the different aspects of teaching. Since the SCAN system proves easy to use, it is open to those who are interested to repeat our qualitative experiments and thus to decide how far they feel that the SCAN record contains the essentials of what they want to observe.

We have already given some examples of read-back and will return to look at some SCAN records of teachers working with computer programs in Appendix II, where we shall also illustrate the sort of inferences that might be drawn.

c) Inferences about teaching from SCAN records

Here we enter territory which is only partly explored, since inferences imply context and application; we shall turn to discuss these in more detail in the next section. However, we can report comparisons between impressions of teaching by experienced observers without and with a SCAN record. These showed important changes of emphasis which amounted to qualitative differences and where video-tapes were available for later verification, in each case the SCAN record seem to have produced a truer picture. We give an example. The ITMA teaching unit JANE aims to use the microcomputer to help to teach the idea of mathematical functions; under the teachers' control it presents a series of named figures each of which either adds or multiplies by specific small whole numbers. The pupils are asked to conjecture and check with the computer, the rules for each name. We have video-tapes of 3 teachers from the ITMA project team using the JANE program (for the first time so no firm conclusions can be drawn) with their pupils. These were analysed using SCAN and the results were compared with impressions of the lessons themselves formed by one of us (RF). There were very clear similarities between the descriptions, but also significant differences; in addition the SCAN record provided quantitative information about the teaching styles involved. For example, the program demands conjecture; give Julie the number 4 and she produces 8 - she might add 4 or multiply by 2, or any of a host of other possibilities. Different teachers exploit this openness in different ways. Teacher F worked methodically through the various names, recording the results on the blackboard, while teacher D did only three cases before moving on to combinations i.e. "functions of functions"; he also had a greater number of unresolved pupil hypotheses open at any time than teacher F. The program option in which the computer either gives the function result immediately (A) or only verifies suggested answers (Y), also allowed the teachers to put very different demands on the pupils. Nonetheless both teachers were working in a basically investigational open way, in using this program. SCAN makes this very clear and the record allows various quantitative measures of teaching style. Comparison with SCAN records of the teachers working in other circumstances displays very clearly the changes in style that using the JANE program produced, and allows the teacher to decide how far the program suits his purposes, and to suggest modifications of it. We give these records and a fuller discussion in Appendix II.

5 Applications of SCAN

We believe that there are several areas in which SCAN will prove useful, however, in none of them has there yet been any systematic development or trial, so the remarks in this Section are based on informal impressions and should be taken as ideas and suggestions for further investigation rather than established "facts". Some such investigations are beginning in a number of places and the results will be reported elsewhere; others may like to develop their own applications.

a) Curriculum development work provided the original motivation for developing the scheme, as mentioned above. Any student of the actual course of curriculum development projects in the past must have some doubts about the effectiveness of the feedback mechanisms that, in principle, allow the experience of pilot and trial use in the classroom to lead to modification of the material. The early piloting, which may lead to substantial revision of lesson units, often involves only the authors of the material acting on their unstructured impressions of its use in their own classrooms on a very limited scale. This usually leads to the removal of major flaws; but can hardly be regarded as a credible optimisation procedure even for the few, and atypical teachers involved. More extensive trials, even when they take place, rarely lead to significant revision; any changes tend to be fairly crudely done on the basis of rather vague evidence such as teacher questionnaires.

The reasons for this limited amount of feed-back are clear. The production of a course of any size is a massive undertaking. The originators generally have a fairly clear view of what they want to produce, crystallised out of extensive experience. The drive and effort needed to produce the material, test it to some extent and to push through its publication and dissemination phases militate against either profound reflection or sensitive fine-tuning of the material with a range of more typical teachers, even when resources are available. Further, it may even be that the temperaments that excel at the one activity do not find the other congenial or easy.

It may be reasonable to be content with such procedures when the material being produced is fairly conventional*; they seem to us quite inadequate

* The very limited take-up of valuable new curriculum material is a depressing feature of the last decade or so of curriculum development. It suggests that more attention to these questions of teacher response in the classroom may be helpful.

however, when the changes are profound. That the introduction of the microcomputer into the classroom is such a change is clear; however, we also think that many of the curriculum reforms of the past 25 year, including the "new maths" should also have been treated in greater depth and in the present work we are seeking ways of avoiding making some of the same mistakes.

b) Teacher training. Any system of recording the essentials of a lesson has obvious applications in teacher training and these we have just begun to explore. SCAN records have been made of lessons by student teachers, both without and with the microcomputer. They seem to allow a much more detailed and particularised discussion of what went on in the lesson than the tutor's notes that are normally used. In particular the nature of the dialogue close to crucial decision points in the lesson can be analysed in retrospect and often leads the students to suggest changes to try on another occasion. The records of experienced teachers working in a variety of different situations may also provide valuable discussion material for teacher training, indicating the very wide range of possibilities that are open to the student teacher and allowing them to select ideas from among them to try.

In looking at SCAN records we have detected characteristic patterns, or rhythms, in the dialogue of individual teachers that recur often enough to suggest that they are important units in the building of a lesson. More extensive studies of each teacher are clearly needed to elucidate this point. If it proves so, it suggests that detailed "tuning" of these crucial elements may help improve the teacher's effectiveness. This too, is an area for further work.

c) SCAN in classroom research. The search for adequate control of experiments in all human sciences tends to lead to fairly simple questions and to the use of measures in answering them that leave the detailed cause of observed effects wide open to speculation; pre- and post-testing of alternative packages, for example, compares only the total effect of the packages without showing which aspects of them are crucial. The clinical or case-study approach on the other hand yields far richer information but of a largely qualitative kind. SCAN provides a tool for detailed structured study of interactions allowing quantitative measures of these variables. It is therefore, potentially a very useful tool, though serious work on the realising of the potential lies in the future.

Here we shall only bring together some of the simple measures, derived from SCAN records, that have seemed to us significant. We have just mentioned the recognition of characteristic teaching patterns - the frequency of use of each pattern , its role in the lesson and pupil response (oral or written) to it might be supplemented with direct measures of the pupils' achievement on the point in question.

Explicit qualities like "openness" can be observed and measured in various ways, e.g.

- by the frequency of γ- questions
- by the number of pupil hypotheses and how long they remain unresolved.

These may be averaged over the lesson or related to particular types of episodes.

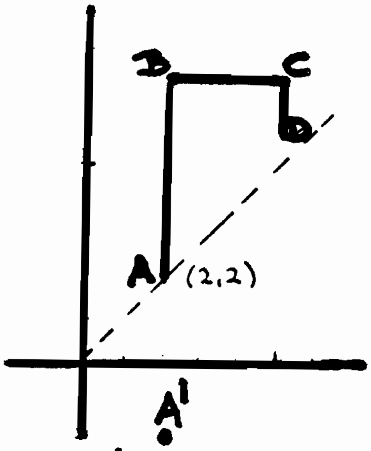
The distinction between teaching processes and products of learning may often be blurred in the mathematics classroom. SCAN can help to clarify this distinction. In a lesson in which the teacher deliberately encourages pupil conversation and discussion of mathematical matters, the extent to which such conversations occur indicates an aspect of the teaching process in that lesson. However, the extent and level of mathematical discussion amongst pupils also indicates an outcome of the teaching processes employed. The ability of a pupil to engage in a sensible discussion on a given topic gives an indication of his mathematical achievement. It must be said that we have particular difficulty in extracting the essentials of pupil-pupil dialogue in making SCAN records - this largely reflects the laconic nature of most exchanges which contrasts with the clear and explicit externalisation which the teacher's skill encourages in other aspects of the dialogue. However, the use of SCAN in describing some aspects of pupil responses indicates that application of the scheme in a concentrated fashion to pupil remarks and actions may yield information of value in assessing the worth of pupil contributions. It may also aid investigators who wish to determine the extent and nature of the immediate learning which occurs during classroom interchanges. Comparisons of such immediate learning with longer term retention of the concepts involved will be of interest.

Appendix I

Here we illustrate the nine different combinations of $\{\alpha, \beta, \gamma\}$ and (1, 2, 3) as applied to questions. Since the context is all-important we order the examples to suit that.

The first six examples occurred in a lesson on transformations of sets of points in the co-ordinate plane and combinations of these transformations.

Context At the commencement of the lesson the teacher placed this diagram on the blackboard.



Event Suppose A^1 = (2, -2), what kind of transformation is this?

Qualification q β 2

Reasons β - pupils must recall the various transformations they have met and carry them out to see if they take A to A^1.

2 - pupils will know that the answer comes from a fairly small set of possible responses - translation, reflection, rotation, shear, enlargement; but as this set must be formed by them before the choice is made, 2 is prefered to 1.

Context As it became clear to the teacher that the class could not think of other transformations besides translations, which had been considered in the previous lesson, the teacher asked:

Event "At the beginning of this topic (one week ago, though the observer would not normally know this) we considered other transformations, can you recall them?"

Qualification q α 1

Reasons α - recall

1 - pupils only had to choose any one transformation from among those recalled from previous discussion.

Context After the answer 'rotation' was provided for the previous question the teacher then asked:

Event "Could this transformation (which takes A to A^1) be the beginning of a rotation?"

Qualification q β 1

Reasons β - requires pupil to try rotations on the given figure to decide if there is one which takes A to A^1.

1 - yes or no answer

Context After giving sufficient information for class to decide that the transformation involved is a reflection in the x-axis and revising the equations for the x and y axes, the teacher then pointed to the line (y = x) on the blackboard diagram and asked:

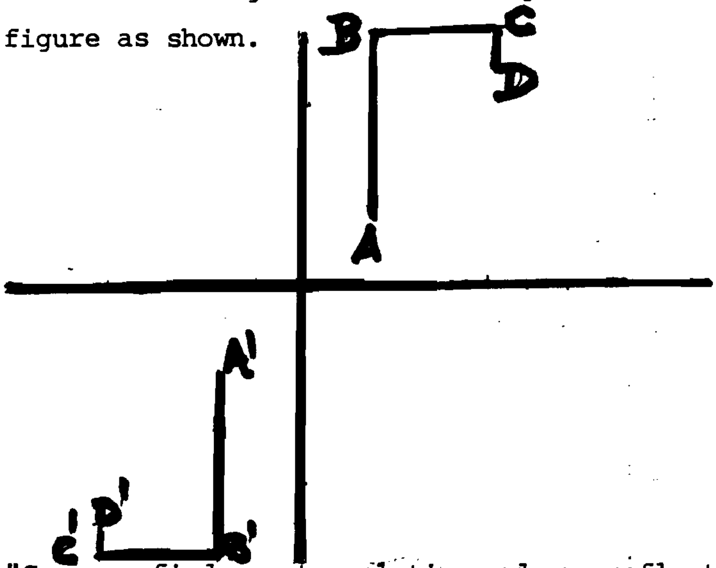
Event "What is this line called?"

Qualification q α 2

Reasons α - it is likely that the pupils would have met the required equation before. The context of the question suggested that the teacher expected recognition rather than deduction of the equation from first principles.

2 - though the pupils would not expect a complicated equation, there would be need to test the simple ones they knew for appropriateness to the given line. (1 could be more appropriate, because y = x is probably the next thing they would think of after x = 0 and y = 0.)

Context Following consideration of the reflection of the given figure in the x axis, y axis and y = x, the class was then given another image of the original figure as shown.



__*Event*__ "Can you find one translation and one reflection which together take ABCD to $A^1B^1C^1D^1$?"

Qualification q β 3

Reason β - an exercise in the context of this lesson when the pupils had been considering transformations of ABCD.

3 - the pupils had no guidance as to which translation or reflection to use to achieve the required transformation and if fact no such translation - reflection pair exist.

Context At a later stage in the above lesson the teacher was discussing the results of the pupils' activity on searching for translation-reflection pairs and asked.

__*Event*__ "Can anybody explain why it is impossible to achieve the transformation using one translation and one reflection?"

Qualification q γ 3

Reasons γ - an idea not likely to have been considered before requiring an explanation involving the reversing effect of reflections.

3 - no teacher guidance given in formulating the explanation (apart from providing the situation for investigation); the teacher had not focussed the class's attention on this aspect prior to the question.

To illustrate the use of other qualifiers it is necessary to consider an earlier lesson involving the same class and teacher as above.

Context The teacher had set an exercise for the class in which they took a particular shape and applied a translation to it and then applied a second translation to the image from the first translation.

Event "See if you can find one translation which is equivalent to the two given translations (carried out successively)

Qualification i γ 1

Reasons γ - it was unlikely that the class had previously met the idea of compounding translations (this matter could be resolved in discussion with the teacher after the lesson, and highlights the need for the procedure adopted in using this system of recording in as much detail as possible, any question which is assigned a γ qualification)

1 - the situation the pupils had to deal with was clearly specified, assuming that these third year pupils were completely familiar with the use of co-ordinates and translation vectors.

Context As an extension exercise following discussion of the above exercises, the teacher provided a vector representing the first of two successive translations of the given figure, and a vector representing the compound translation and asked the class to find the vector representing the second translation.

Qualification of Event $i\gamma 2$

Reasons

γ - although related to the previous exercise this task contained a new aspect of mathematical thinking

2 - though the situation was well defined as before and the pupils knew something of how the vectors combine, the teacher has given no clue on how the pupils might go about obtaining the answer.

In practice it is difficult to regard the two scales of qualifiers as being unrelated to one another. By their nature αquestions are unlikely to show the wide variance in openness which is observed with γ- questions. It must be understood that when 1, 2, 3 are applied to α-questions the range 1 → 3 is not as great as when applied to γ – questions. It seemed sensible to use all nine categories in the cells of the $\{\alpha,\beta,\gamma\} \otimes (1,2,3)$ matrix so that a specific type of question which was covered by the 3 qualification was sought. A possible candidate for this class of question is the following "disguised guess":

Context

The teacher introduced a new function to the class with the situation

$$5 \longrightarrow \boxed{F} \longrightarrow ?$$

and <u>encouraged pupil speculation</u> on what the function might be.

Qualification of Remark $q\alpha 3$

Reason

Pupil speculation amounted to little more than selecting a number (α task) with no other guidance from teacher.

Appendix II

Here we shall discuss further how SCAN might contribute to curriculum development by looking at the feed-back it provides on the early use of two teaching computer programs. In both cases the teachers involved were using the programs for the first time in the television studio, so no realistic conclusions can be drawn. However, the records do serve as vivid illustrations of the way in which SCAN revealed teaching styles and the changes that can be produced in them by computer teaching units.

The first three illustrations are of short 20 minute lessons using the program JANE described in Section 5. Two of the three teachers, D, E and F, are in fact teachers A and B studied earlier; the reader may care to try to identify them. We shall not provide a detailed read-back of each lesson, believing that the SCAN record provides more information in a form which, we hope, is now accessible to the reader. Rather we shall draw some of the inferences we see in them, referring also to lessons A1 and B of section 2 for comparison.

All three lessons consist largely of search-successful episodes in an exposition mode, with the teachers using the computer in interaction with the whole class. All three contain large numbers of extension γ - questions and an impressive rate of generation of hypotheses by these first and second year pupils, which goes far beyond anything in lessons A1 or B. These features are common to the way all three teachers use the program, but quantitatively there are clear differences, some of which are shown in Table VI.

LESSON IDENTIFICATION : D.

Resources Used	Activity	Event/Episode Summary	
C	E	What is David doing? have we done enough? m | qγ3 (1A) hhr | qβ2 (iα1) hhc | qγ3 o | ch | v | qβ1 hhc | R →	1
		c ‖ SS Mary qα3 (1Y) hhr hhr (qγ3 o) hhr hhr (eα1) (1A) hhr | qβ2 (1Y)	2
		hhr hhr hhc | qβ1 hhr hhr hhc | qβ1 hhc | qβ1 hhc ‖ SS	3
		Peter qα3 (1Y) hhr hhr hhr (Is it worth guessing? qγ3 o) hhr (1A) | qβ2 (1Y) hhc ‖ SS	4
		Susan Fred g | iα1 (2A) | qα3 hhr | qγ3 (PP) (2Y) h_1 h_2 (what could each be doing? qγ3 o) h_2r h_3	5
		(peγ3 | ch) h_3c what are S, F doing? qγ3 h_1 (peγ3) h_2 (peγ3) h_3 h_3c |	6
		qβ1 v | aβ1 ‖ SS Fred Julie qγ3 (2A) hhr (2Y) hhr | peβ2 | qβ1 hhc ‖	7
		CP/SS Julie Paul 9→41 5→? qγ3 (2A) (2Y) hhr hhc | g | peβ2 | qβ1 hhc ‖ SS/CP	8
		Peter Julie 6→16 5→? qγ3 (2A) (2Y) hhr hhc | peβ2 | qβ1 hhc ‖ CP/SS	9
		Paul Susan g (2A) | qγ3 (2YD) hhc | peγ3 | hhc hhc h_1 (peγ3 | ch | peγ3 | ch |	10
		eβ2) h_2 h_3 h_3c | does it matter which way? qγ3 h_1 h_2 (peβ2) h_2c ‖ SS Fred Helen does it matter which we try? qγ3 o | (2A) (2YD)	11
		what do they do? qγ3 (PS) hhr hhr h_1 x c h_2 h_3 (iβ2 | PP (peβ2)) h_2c	12
		h_3r ‖ SS Fred Helen what are they doing? qγ3 (2Y) hhr h_1 (eβ2) h_2 h_2c x (eβ2)	13
		h hhr hhr hhr (peβ1) hhr hhr (m | eβ2 | aβ2)	14

LESSON IDENTIFICATION : E

Resources Used	Activity	Event/Episode Summary	
C 1 BB 2	E	What is Paul doing? m |g| iα1|ch| qγ2 o o (qβ1 x ✓) ✓| qβ2 x x x R1 (1A)	1
		(eβ2) x ✓ R2 || SS Fred 5→7 4→6 qβ2 (1A) h (qβ1✓) hc || SS	2
		Peter 3→7 qβ2 (1A) h hc || SS Julie 3→6 4→8 qβ2 (1A) h hr | qγ2 h hc || SS Helen 6→24 qβ2 (1A) h1	3
		(qα1 x x ✓ | ch) h2 (qα1✓ | qγ1 ✓) h1c || SS Can we tell with one? Mary qα3 (1Y) (pa)	4
		What does ∞ mean? h hr h hr h hr h hr (qγ3 x) h hr h hr h hr h hr h hr h hc |	5
		qβ2✓ || SS Julie 6→? qα1✓ (1Y) | qβ1 h x | qα3 h hr h hr h hr h hr (a good way of trying? qγ3x |	6
		a good no to start with? eβ1 | qγ2✓ | z) || SU Mary qα3 (1Y) h hr h hc | qβ2 ✓ || SS	7
		iα1 (2A) | qγ3 . . . . . Helen Peter 3→16 5→24 h (qβ2✓) hr (g) h hr h hr (ps) 4→20 h hr (m|g|	8
		eβ2) h hr (qβ2✓) h (qβ1✓) hc || SS Susan Paul 2→12 qγ2 (2A) h1 (g) h2 (peβ2|	9
		eβ2) h3 h4 h5 h6 h6r (qβ1✓) 4→18 h7 h7r (eα1) h8 h8 h9 (peβ2|	10
		eβ2) h4c | -1→? qβ2 (2Y) h hr o (qα1 o |eβ1) R2 h hc || SS Helen David 1→7 qγ2 (2A) h ✓	11
		(eβ1 | psβ1) hr (PP..) h (eβ1 | x | eβ1) hc | -8→? qβ2 (2Y) (PP..) h1 h2 h3	12
		h4 hxr hpr (qβ2 o R2 | eβ2) h5 h6 (pb) h7 (eβ2) h7c	13
			14

LESSON IDENTIFICATION : F

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Event/Episode Summary</th><th></th></tr>
<tr><td>PMB 1 C 2</td><td>E</td><td>What does Jane do
g | m | eγ2 | x | eγ1 | qγ3 (1A) h_1 h_2 (qβ2 ✓) h_2c | qβ1
R_1 R_2 → R_3</td><td>1</td></tr>
<tr><td>BB 3</td><td></td><td>✓ hhc || SS   Julie qβ2 (1A) R_3 $h_1$$h_2$ (qβ1✓) h_2c || SS   John qβ2 (1A) h∧o (eβ1)</td><td>2</td></tr>
<tr><td></td><td></td><td>hc || SS   eβ1 R_3 | qα1 ✓ R_3 || E   Jane qα1 ✓ (1A) | qβ1✓ || SS   m | m |</td><td>3</td></tr>
<tr><td></td><td></td><td>Paul qβ1 (1A) hhc || SS   eβ2 || E   Mary qβ1 (1A) $h_1$$h_2$ (qα1✓) h_2c || SS</td><td>4</td></tr>
<tr><td></td><td></td><td>Pattern? qγ3 ✓ || SS   Julie qα1 (1Y) hhc || David qα3 (1Y) hhr hhr hhr</td><td>5</td></tr>
<tr><td></td><td></td><td>hhr hhr hhr hhr (eα1) (1A) h (qα1✓) (1Y) hc || SS</td><td>6</td></tr>
<tr><td></td><td></td><td>Jane qα1✓ (1Y) || m | m   Peter qα1 (1Y) o | qβ1 hhr hhr hhc || SS R_3</td><td>7</td></tr>
<tr><td></td><td></td><td>qα1✓ | m || Peter Mary qγ2 (2A) hhc || SS   Susan David g | qγ3o (2A) how tackle</td><td>8</td></tr>
<tr><td></td><td></td><td>(qα1✓ | qα1✓ | eγ2) qγ2 hhc R_3 || SS   Jane John qγ2 (2A)</td><td>9</td></tr>
<tr><td></td><td></td><td>(qα1✓)✓ || SS   Helen Peter g | qα1✓ (2Y) | eα3 | qα1✓ (2A) | qγ1 (2Y) h</td><td>10</td></tr>
<tr><td></td><td></td><td>(qβ1✓) hc || SS   Jane Fred qα1 ✓ (2Y) | aα1 | qα3 h (qβ1✓) hr</td><td>11</td></tr>
<tr><td></td><td></td><td>h (qβ1✓) hc R_3 || SS   Jane Peter m | qβ2 (2Y) hhr hhc || SS</td><td>12</td></tr>
<tr><td></td><td></td><td>John Mary pqα1 (2Y) | qβ2 hhc || SS   David Susan qβ2 (2Y) hhc || SS</td><td>13</td></tr>
<tr><td></td><td></td><td></td><td>14</td></tr>
</table>

Table VI

Lesson		D	E	F
questions asked (resolved)	α	3(0)	7(5)	17(15)
	β	10(10)	17(14)	15(15)
	γ	15(9)	9(7)	7(6)
explanations		6	12	8
assertions/ instructions		4	2	1
pupil questions		0	0	1
pupil explanations		11	4	0

The different proportions of α, β and γ questions used by the three teachers, the use by F of α - questions to provide guidance where E more often uses direct explanations, and the number of pupil explanations in D's are striking features. (Do the other pupils generally understand?) E regularly digresses from the main stream of hypothesis generation and checking by inserting clarifying questions, and both E and F use supporting explanations, or questions at level 1 which are similar, more than does D.

F has many more episodes than the others, representing more, but shorter successful searches. They include a thorough, indeed almost complete, exploration of the single functions in the program, and the results are recorded on the blackboard in each case (R_3). With this basis the double function searches become largely deductive exercises. In contrast teacher D spends a short time dealing with only three of the single functions before embarking on high demand searches in the more complex problems; in each of these searches a wider range of hypotheses was advanced, often with explanation by the pupils, before using the computer to provide the information to resolve them. D also used the Y program mode, in which the computer does not explicitly give the function output value, early in the lesson in a long and demanding episode. A detailed look at each record shows immediately the very different dialogue patterns employed by the three teachers.

Looking back at lessons A1 and B, it is clear that both these teachers in working with JANE adopt a significantly different style involving much more pupil hypothesis. Of the two, the more supportive F = B remains so, but this lesson is at a consistently higher level of demand though the guidance remains fairly strong (c.f. lesson D). Teacher E = A continues to show a complex pattern of dialogue, pursuing intesting sidelines which illuminate the main theme.

The picture that emerges of the JANE program is of a highly successful teaching unit in which quite young pupils successfully respond to a high level of mathematical demand. It seems to be flexible enough to be employed by teachers exibiting widely different teaching styles. In the face of such impressive results, the reader many reasonable wonder if there is any useful role for SCAN in developing material of this kind.

This remains to be demonstrated but there are features of the program which have since been improved as a result of the feed-back provided on its use, including SCAN record and others suggest themselves. The "accidental" occurrence of negative numbers and the too early use of the Y option are examples. The lessons are entirely in exposition and some pupils may have taken no active part in them - should the program format be altered to stimulate specific individual or group acitivity by the pupils, perhaps by introducing a competetive format? The problem of computer dominance is one that should be considered - should the program suggest to the teacher at intervals a change of pupil activities undistracted by the computer? Would there by a value in its provoking explicit written work aimed to reveal the state of understanding of individual pupils?

These questions are merely illustrative. The artificial nature of the lessons and the teachers' intention to explore the possibilities of JANE make it likely that they would have balanced their lessons differently in more normal circumstances when they became familiar with the program. It is likely however, that similar questions will arise with the developing of teaching units and we believe that SCAN will contribute to their clarification and solution.

We shall now discuss the SCAN of a lesson (A2) taught by teacher A, in which exactly the same content was covered with the other half of the same class of lesson A1; in this case however, the teacher used a computer program to display the plane translations being discussed. At our request this program was a rough draft version, untested before the lesson concerned, providing an interesting extreme example from an experimental point of view. The opening exposition at the blackboard starts with straightforward questions, checked with several pupils, and an explanation before the computer is brought in. Alternating explanations and questions at α1 level give a very detailed picture of the procedure expected from the computer program whose next response (line 2) is erroneous. The following explanatory dialogue, which contains a number of management remarks and a vote to check that the class is in touch is conducted almost entirely at α-level apart from the computer assertions; this contrasts with teacher A's general use of a β-level of demand. Two further slips in line 4 lead to the temporary abandonment of the computer as the teacher uses the blackboard to help initiate a brief pupil exercise. The next exposition is crisper and more successful guided by an exercise; an extension question leads to a pupil hypothesis which is confirmed using the computer. The principle of composition of plane translations is established, at least for some. The teacher then turns to the blackboard to set up an exercise involving the idea of an inverse - a difficult extension problem.

Working in groups of four a pupil-pupil dialogue of a typical check and assert variety is augmented by the teacher. The computer is brought into action and again causes problems, with a flurry of managerial remarks, however, it gets going and generates some quite interesting work with the third pupil hypothesis being finally confirmed (is hypothesis 1 still left in the air?). Another go (line 13) with a computer posed problem yields a quick success.

LESSON IDENTIFICATION : A2

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Event/Episode Summaries</th><th></th></tr>
<tr><td>BB, C</td><td>E</td><td>m | qα2✓ | ∧x✓ | ∧✓ | e | m | eα1 | qα1✓ | eα1 | (BB, C)</td><td>1</td></tr>
<tr><td>(3 min.)</td><td></td><td>qα1✓ | eβ1 | m | qα1✓ | x (c) | cα1 | m | v | qα2✓ |</td><td>2</td></tr>
<tr><td></td><td></td><td>eα1 | qα2✓ | eα2 | caβ2 | m | m | m | qα2✓✓ |</td><td>3</td></tr>
<tr><td></td><td></td><td>caβ2 | m | dα1 | eα1 | x (t) | eα2 | m | x (t) |</td><td>4</td></tr>
<tr><td></td><td></td><td>caβ2 | eα1 (BB) | iβ2 || E, I.</td><td>5</td></tr>
<tr><td></td><td>W1</td><td>m</td><td>6</td></tr>
<tr><td></td><td>E W1</td><td>what is composition?
iβ2 | qγ2 h (qβ2✓ | caβ2) hc || SS</td><td>7</td></tr>
<tr><td>(12 min.)</td><td></td><td>given result, what is second one?
eβ2 (BB) | iβ2 | ch | iβ2 | iγ2 | m || I</td><td>8</td></tr>
<tr><td>2 1
3 4</td><td>W4</td><td>PP (1ch₀ | 1a | teβ2 | 4a | 1a | tch | tm)</td><td>9</td></tr>
<tr><td></td><td>D W4</td><td>c m | m | m | caβ2 | m | eβ2 | m | m | m |</td><td>10</td></tr>
<tr><td>(17 min.)</td><td></td><td>caβ2 | m | qβ2 h_1 (m) h_2 (m | caβ2) $h_{2}r$</td><td>11</td></tr>
<tr><td></td><td></td><td>h_3 (m | caβ2) $h_{3}c$ || SS   ch || CH</td><td>12</td></tr>
<tr><td>(21 min.)</td><td></td><td>g | m . . . . || CH   ph (qβ2✓ | caβ2) hc || SS</td><td>13</td></tr>
<tr><td>(26 min.)</td><td>E</td><td>c m | m | qα1✓ | m | cα1 | m | qβ1✓ | m | C(P) |</td><td>14</td></tr>
</table>

<table>
<tr><th>Resources Used</th><th>Activity</th><th>Event/Episode Summaries</th><th></th></tr>
<tr><td></td><td></td><td>how do we check case?
m | m | qα1 0 | aα1 | m | caβ2 | qγ2 h(qβ20 |</td><td>15</td></tr>
<tr><td></td><td></td><td>what is second translation?
ch | qα100 | eα1 | qγ2 h_1(qγ20(eγ2)0</td><td>16</td></tr>
<tr><td></td><td></td><td>(iβ2) 0 h_2(eβ2) h_3(m | eβ2 | ch | eβ2 | m |</td><td>17</td></tr>
<tr><td></td><td></td><td>how do we check?
qβ2✓ | eβ2 | qγ2 | $\overset{t}{x}$ | eβ2) Λ 0(eβ2)0
BB</td><td>18</td></tr>
<tr><td></td><td></td><td>Λ✓) | eβ2 || SS? c qα1✓ | qβ2h
BB</td><td>19</td></tr>
<tr><td></td><td></td><td>(caβ2) hc || SS qα1✓ | qβ1 h(m | m | m |</td><td>20</td></tr>
<tr><td>(39 min.)</td><td></td><td>caβ2) hc || SS similar episode with another group.</td><td>21</td></tr>
</table>

Back to exposition with the computer, and more suggestions of difficulty in the density of managerial comments and the α-level of the transactions. The teacher raises the demand with two γ- questions but, despite further leading, fails to get any pupil response and has in each case to explain the point in question, though things improve a little by the end of the episode, when the teacher turns from the computer to the blackboard. Persistence pays however, and the lesson concludes with two successful exercises using the computer.

Thus in this lesson the very rough computer program used causes the teacher difficulties at several points without any obvious educational compensations (though this last could only be established by looking carefully at pupil work); in a later lesson the teacher actually abandoned the computer when parallel problems arose. Though unstructured observations of the lessons would have noted these fairly severe difficulties, the SCAN record pin-points their nature and occurrence in the teaching sequence. This illustrates the importance of thorough development and testing of such programs and indicates how using SCAN may contribute.

Appendix III SCAN 1M - a fuller discussion of the system

Here we give a detailed discussion of the meaning of the terms used, as given in Table VII at the end of this section. We begin with the events, going on to discuss episodes and activities later.

Events

The categories of event chosen for use in this study may be conveniently viewed in two groups, as follows:

A Social, Organisation, Procedural

gambit (g)
managerial (m)
question for checking (ch)
vote (v)
(silent observation) (o)
withdraws statement (w)
(leaves discussion) (l)

B Associated with Content

Event	Group
question of content (q)	
assertion (a)	informational statements
explanation (e)	
giving example (x)	
conclusion (cc)	
boing (b)	
suggestions (s)	directions to activity
instructions/initiation (i)	
confirmation (cf)	dealing with responses
rejection (r)	
correction (k)	

The first group of categories covering events which have social, organisational or procedural purposes is smaller than the second, which contains events related to mathematical content and this reflects the major interest in this approach. The categories in group A are designed to record events which, although not directly associated with content, are, nevertheless, important in describing the manner in which mathematical discourse is conducted.

Gambits are similar to the *markers* of Sinclair and Coulthard,[5] and usually indicate the speaker's intention to enter a mathematical discussion in a socially acceptable way. An event such as "What is the problem here, then?", would be classified as a gambit.

Managerial events are clearly concerned with organisational procedures within the class. The instruction "Turn to page 103 and look at exercise D" is an example of a managerial event.

A *question for checking purposes,* such as "What did you get for number three?" has the intention of gaining information about the existing situation so that the speaker may structure appropriate further events.

When a teacher calls for a *vote* such as "How many got the answer three and how many got five?", they are in fact assessing the state of understanding of the class, again in order to structure appropriate further events.

The category *observation* may consist of actions only as well as remarks such as "Oh, I see what you've done". This category was found to be useful as an indication that the speaker has taken time to become familiar with the written response of a pupil before structuring events to follow.

The category *withdraws statement* is used to record occasions, usually in pupil-pupil dialogue, when a pupil indicates that they wish to withdraw from a position that they formerly held. If possible the statement which has been withdrawn should be indicated.

The action of *leaving a discussion,* not necessarily with an associated remark has not been observed in the videotapes studied. The need for this category was suggested to the writers by the behaviour of R. Davis, of Madison Project fame, in a film where he was teaching a bright group of teenagers a lesson on sequences. Here, after throwing a number of remarks into a discussion, he deliberately stayed out of the discussion to allow the pupils to bounce their ideas off one another. As a possible desirable teaching act it was felt useful to have the capacity to record such moves even though they may not occur frequently.

Turning to the events associated with mathematical content, four subgroups of events may be identified. These are *questions of content,* which are the *elicitations* of Sinclair and Coulthard, *informational statements (informatives* of Sinclair and Coulthard), *directions to activity (directives* of Sinclair and Coulthard) and ways of *dealing with response.*

Informational statements includes event categories which cover the range of different ways in which a mathematics teacher may impart information without the use of questions. *Assertions* occur when a piece of information is provided without supporting justification. An example of an assertion is "The sum of the angles of a triangle is 180 degrees".

Definitions are similar to assertions in that reasons for the statement are not offered, but here it is clear that a mathematical entity is being defined. The statement "A scalene triangle is a triangle in which all of the sides are of different length" is a definition. The term should, if possible, be reserved for statements which supply mathematically complete definitions. The statement "A square has all its sides the same length" would be best classified as an assertion.

As many authors have pointed out, *explanations* may be of many different types. The detection of these fairly subtle differences was felt to be beyond the capacity of a "real time" observer, apart from the use of qualifiers which was discussed in Appendix I. Consequently, explanation is a category which is used whenever the speaker attempts to indicate "what", "how" or "why".

The event category *giving an example* is often used in conjunction with a definition. After defining a plane using the words "flat surface", a teacher was observed to supply an example "like the table top" to give the pupils a better image than that supplied by words alone.

Though not used in the early stages of development of the current observation system, it appears useful to include *conclusion* among the categories. This category is useful in distinguishing assertions made on the grounds of previously assembled evidence from those made in the absence of such support.

The title of the category *boing* was chosen for its suggestiveness of the event it describes as well as for its hitherto unused initial letter. Into this category are placed those events made by pupils which clearly indicates that they have undergone the "eureka experience" such as "Now I get it!" It is suggested that pupils will not respond in this way unless they genuinely get the point, however, the category should be used with care because of its potential significance.

Sinclair and Coulthard distinguish *directives* (Requiring non-linguistic responses) from *elicitations* (requiring linguistic responses). In mathematics lessons it was found that directions to engage in mathematical activity lie on a spectrum *instruction - initiation,* with the specificity of the direction decreasing towards the initiation end. Fortuitously, both words start with the same letter and the position on the spectrum of a particular remark may be indicated by the use of qualifiers to be described presently.

Pupils, in particular, often promote mathematical activity by others by making *suggestions* rather than giving directions. Teachers have been observed to make this type of event when they outline a variety of possible approaches which may prove fruitful, without firmly indicating that a particular path ought to be followed. Generally, however, *suggestion* is more appropriately applied to pupil remarks.

The final group of event descriptors indicate the manner in which a speaker treats previous remarks or written responses. *Confirmation* normally occurs when a written response draws a remark such a "Yes, that's right". *Rejection* and *correction* are also used in dealing with written responses, the latter occurring when the reason for rejection is made clear or a more appropriate response is indicated.

In general when classifying the linguistic role of a particular event, the observer views it, as far as possible, in terms of how it is perceived by the pupil. For example, rhetorical questions are either assertions or explanations, and interrogative statements are questions.

Events made by unspecified pupils during interactions involving the teacher are prefaced by p. During pupil-pupil interactions, a teacher event is prefaced by t. Further identification of events with specific pupils is discussed near the end of this section. Events for which a computer is responsible are prefaced by c.

The treatment of verbal responses to questions has been tied to the particular question by the use of a separate set of symbols for the various ways in which the response may be handled.

✓ following q indicates that the question was correctly answered

q ✓ indicates that the answer was not rejected, though it was not all that the question required

q ✗ indicates that the answer was incorrect

q ... indicates that appreciable time has been allowed to think about the answer

q o indicates that no pupil offered a response or that a particular nominated pupil failed to respond

$\overset{\checkmark}{h}$ following q indicates that an answer (hypothesis) has been offered which to the observer's mind is suitable, but the questioner has not indicated his opinion of the answer

$\overset{\times}{h}$ is used in similar circumstances when the observer feels that the answer offered is inappropriate

hc, hr may follow at a later stage if the hypothesis is confirmed, or rejected.

To allow for the fact that events may occur between an hypothesis being offered and its final rejection or confirmation, ( ) are used to enclose these intervening events.

It is of interest to note that the need for the last five symbols (h to brackets) was not apparent until an attempt was made to describe the interactions occurring in certain lessons in which the microcomputer was used. They have subsequently been found to give a more structured record of some of the lessons studied earlier in which the computer was not used.

To complete this set of descriptors for the fate of questions t_o is used when the teacher does not allow willing pupils to answer and either answers the question himself, recorded as an assertion, or goes on with another event.

No special symbol has been adopted to record the phenomenon of the teacher answering his own question. This can normally be deduced from the pattern $q\beta 20/a\beta 2$, that is, an assertion of the same content (β and 2 are explained below) following an unanswered question.

Before leaving the recording of questions, it has been noticed that the same question often appears at different points in the discourse, in some cases having been modified. If this is observed, it should be recorded, if possible, by underlining the questions which are the same.

An important aspect of this study is the attempt to describe the mathematical nature of classroom discourse and the nature of the demands upon thinking made during the lesson. To reduce the demands of such detailed analysis during real time lesson observation a compact system for qualifying the nature of events has been devised. This system consists of two three-point scales which are used to assign to each event an indication of its -

(i) depth of demand on the mathematical knowledge of the pupil

(ii) level of guidance offered

The categories of the qualifiers used and their codes are as follows:

<u>Depth of demand on the pupil</u>

α - recall of single fact or step in process, simple mathematical observation which does not require any processing of facts

β - of exercise nature, putting together two or more previously encoutered mathematical facts or steps

γ - an extension of previous skills and understanding in which new skills and understanding are required or developed

Level of guidance

1 - highly structured or closely guided situation in which the pupil sees only a small number of possible choices

2 - some guidance present but pupils required to make connection rather than mere selection

3 - minimum guidance level, including open and investigatory questions.

These qualifiers were developed with the notion that their main application would be in describing questions, but it is possible to use them to qualify other events, notably explanations and initiating statements. To illustrate the application of the qualifiers, a number of examples have been given in Appendix I.

Episodes

Having considered the main aspects of recording at the event level, we now turn to the provision of *episode* summaries. When the observer feels that an episode, characterised earlier as involving a single, simple content or process objective, has finished, this is recorded by the use of the symbol // . At this stage the observer attempts to make an on-the-spot classification of the episode using a number of categories formulated in the present study of mathematics lessons. If, on subsequent analysis, the event record of an episode indicates aspects that the observer did not notice at the time, then modification of the episode summary, preferably by addition only, may be appropriate.

The categories used for summarising episodes which require little or no explanation are as follows:

Defining (D)	mainly definition (d) events present
Initiating activity (I)	mainly initiatory (i) events present
Coaching (CO)	here the teacher explains material which has already been covered, helps pupil to overcome difficulties, may include correction (k) events.
Explaining (E)	extending knowledge, presenting new material

Confirming (C)	pupil's performance is reinforced and he is encouraged to continue
Revising (R)	explaining or reminding pupils of previous material
Searching Successfully (SS)	episode results in the resolution of an issue under consideration
Seaching Unsuccessfully (SU)	episode ends without resolution of the issue under consideration. Teacher may then supply more information or adopt new approach
Conversing (CN)	teacher-pupil or pupil-pupil discussion of a mathematical matter is which both speakers make significant contributions
Facilitating (F)	contains managerial moves made by the teacher in helping pupil move to mathematical task
Arguing (Resolved) (AR)	consensus achieved after difference of opinion (usually pupil-pupil dialogue but may occur between pupil and teacher)
Arguing (Unresolved) (AU)	difference of opinion where no consensus is achieved (unlikely to occur between pupil and teacher)
Competing (CP)	situation in which pupils are striving against one another or the teacher

Activities

The major *activity* phases of a lesson are:

Exposition (E)	the teacher commands the attention of the whole class (E_w) or a group of five or more pupils (E_n)
Pupil work (Wn)	the puils are working idependently of the teacher in groups of size n. (Wl - working individually)
Dialogue (D)	teacher talking to individual pupil or a group of five or less. Or a group of pupils are discussing a mathematical topic.

It should be pointed out that the recording form requires the entry of activity categories in a different column from the area in which episode summaries are placed so that the use of the symbols D, E in each category presents no difficulty.

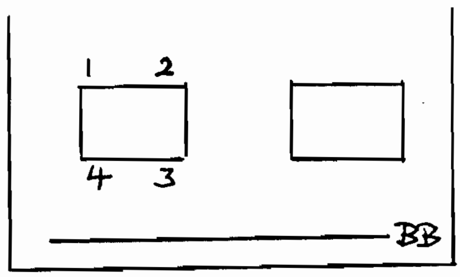
When *dialogue* occurs, there other symbols may be used in the activity column

PP - indicates that pupils are engaged in dialogue. If the teacher enters this dialogue, his events are prefaced by the letter ' as distinct from other phases of the lesson in which pupil events are prefaced by the letter p.

T and P may be used in the activity column to indicate whether the dialogue was initiated by the teacher or by a pupil.

Whilst considering the tagging of events to specific speakers during dialogue, it is opportune to describe the technique used for identifying speakers in pupil-pupil dialogues. Such a procedure is of value as the identification of speakers allows possible correlation of the events made with the work output of particular pupils.

The technique adopted is to provide a sketch plan of the seating arrangements of the pupils whose dialogue is recorded. Assuming that pupils generally work in the same place, numbers are assigned to each pupil shown in the plan and these numbers are then used to identify the speaker in the event record. A typical sequence might be recorded as 2qα2 / 1aα3 ... where the first number in each quadruple identifies the speaker and the second number is the guidance level of the event. Identification of the pupils may be achieved in consultation with the teacher after the lesson for use in relating events in the lesson record to photocopies of the pupils written work. A pupil seating plan of the type shown below has proved effective in observations:



As this study aims to supply feedback to teachers on the effects of using a computer as a teaching resource it is essential that the observation record allows for the recording of the points in the lesson at which the teacher uses a various resources. The commonly used resources have been allocated codes and these may be recorded is a separate column of the record sheet and also shown at the points in the continuous lesson record when the teacher uses and them ceases using the resourece. The codes for recording resource usage adopted in this study are

TM - teacher produced material, work sheets etc.,
PMB - commercially printed material, text books,
PMC - commercially printed material, work cards,
C - computer
BB - blackboard
OHP - overhead projector

The observer is at liberty to include any information onresource usage which he thinks is significant and is able to incorporate in the lesson record.

The specification of the nature of computer material and the integration of this specification with the lesson record is important but it will be discussed elsewhere.

It was found to be useful to incorporate a number of miscellaneous symbols for recording events which have been observed to occur and are thought to be of potential significance. These are

t_x used to indicate a significant teacher slip, whether or not the teacher corrects this slip

c_x used whenever a computer response was not anticipated by the teacher. This may be due to a teacher slip, but the observer may not be in a position to observe that fact.

z used to indicate a major tactical change by the teacher in the course of the lesson.

With each of these miscellaneous codes the observer should, if possible, record sufficient detail to enable a complete identification of the event with the teacher's help after the lesson.

The symbol $\wedge$ is used whenever a event is repeated. This is more commonly found to occur with questions and this provision enables the patterns

$$q\,\beta\,3o\Lambda\checkmark \text{ and } q\,\beta\,3o$$

to be distinguished.

The question of recording the passage of time has not been fully experimented with at this stage. The technique employed to date has been to simply record the time in the lesson sequence whenever the observer finds it possible so to do. This is sufficient to give a rough and ready indication of the timing of a lesson, particularly when, as is often the case, the time can be recorded as activities or even episodes change.

The decision not to investigate the time aspects of lessons more fully at this stage is justified in terms of the descriptive aim of this research. The current aim is to identify and describe typical sequences of interactions occurring in lessons. When such a description is achieved it is them likely that timing will become an important aspect of the analysis of interactions. A possible technical approach to the timing problem is the use of a device which produces a signal, audible only to the observer, at a chosen time interval. The observer may then record a suitable mark in the sequence of recorded events to allow later analysis.

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