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The Cognitive Skill of Teaching

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This article characterizes teaching as a complex cognitive skill amenable to analysis in a manner similar to other skills described by cognitive psychology. A formal model of the process of instruction in elementary mathematics is presented and examined in light of empirical data from both expert and novice teachers. The model's perspective is that teaching skill rests on two fundamental knowledge systems: lesson structure and subject matter. Instructional segments are carefully analyzed in order to clarify the nature of instructional action and goal systems that support competence. The authors also seek to contribute to cognitive psychology by beginning the analysis of a socially dynamic and complex task domain.

We wanted to understand how it is that successful teachers do what they do. We observed teachers whose students had learned unusually well, and we compared these teachers' performance with that of novice teachers. Based on these observations, we propose a hypothesis about cognitive processes and knowledge that provides a basis for effective teaching.

Our hypothesis is based on the characterization of teaching as a complex cognitive skill. This skill requires the construction of plans and the making of rapid on-line decisions. The task of teaching occurs in a relatively ill-structured, dynamic environment. Goals and problem-solving operators are not specified definitely, the task environment changes in a way that is not always under the control of the teacher's actions, and information appears during the performance that is needed for successful completion of that performance. In these respects, teaching is similar to other tasks that have been studied recently such as medical diagnosis (Johnson et al., 1981; Lesgold, Glaser, Feltovich, & Wang, 1981; Pople, 1982) and chess (Chase & Simon, 1973; Wilkins, 1980) and is unlike the simpler tasks of solving puzzles (e.g., Newell & Simon, 1972) and performing specific procedures of calculation (e.g., Brown & Burton, 1978).

We consider skill in teaching to rest on two fundamental systems of knowledge, *lesson structure* and *subject matter*. The first is the knowledge required to construct and conduct a lesson. This knowledge is supported and partially controlled by significant knowledge of subject matter (the second area of knowledge) and is constrained by the unique circumstance or set of students (Leinhardt & Smith, 1985). The second is the knowledge of the content to be taught. Subject matter knowledge supports lesson structure knowledge in that it is accessed and used during the course of a mathematics lesson. Subject matter knowledge constrains lesson structures in that different types of content need to be taught differently. At one level, this is the expected difference between teaching math or another subject; at another level, it is the difference between teaching the introductory conceptual lesson in reducing fractions and the lesson on an algorithm for reducing fractions. Although we are aware of and are investigating these different knowledge bases, the current article focuses almost entirely on the lesson structure portion of instructional skill.

Knowledge for Skilled Teaching

We propose that a skilled teacher has a complex knowledge structure composed of interrelated sets of organized actions. We refer to these organized actions as *schemata*. They are applied flexibly and with little cognitive effort in circumstances that arise in the classroom.

The main feature of the skilled teacher's knowledge structure is a set of schemata for teaching activities. These schemata include structures at differing levels of generality, with some schemata for quite global activities such as checking homework and some for smaller units of activity such as distributing paper to the class. The idea that knowledge for skilled performance consists of schemata at different levels of generality was developed by Sacerdoti (1977). Sacerdoti's system constructs plans for performing tasks by choosing global schemata that satisfy general goals and then by choosing less global schemata that satisfy more specific goals and requirements of the higher level schemata. Sacerdoti's analysis, therefore, shows how a structure of schemata at different levels of generality provides a basis for performance in a complex cognitive task involving integration of high-level goals and actions with their lower level components. The idea has been useful in analyses of the cognitive processes of solving problems in high-school geometry (Greeno, Magone, & Chaiklin, 1979), in programming (Soloway, Ehrlich, Bonar, & Greenspan, 1982), and in the design of computer software (Polson, 1972; Polson, Atwood, Jeffries, & Turner, 1981). We apply it here in the analysis of the complex cognitive skill of teaching.

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A characteristic of skilled performance is that many component actions are performed with little effort because they have become automatic through practice. We conclude that skilled teachers have a large repertoire of activities that they perform fluently. We refer to these activities as *routines* (Leinhardt, Weidman, & Hammond, in press). For routines to be effective, the students as well as the teacher must have developed an organization of actions or schemata for the actions that are performed. Routines play an important role in skilled performances because they allow relatively low-level activities to be carried out efficiently, without diverting significant mental resources from the more general and substantive activities and goals of teaching. Thus, routines reduce cognitive load and expand the teacher's facility to deal with unpredictable elements of a task.

We also hypothesize that the schemata for activities of teaching include structures that we call *information schemata*. In addition to conducting the current activity, a skilled teacher acquires and takes note of information that will be used in a later activity. The knowledge base for skilled teaching includes the kinds of information needed for the various activities of teaching, and provisions for acquiring that information are included in the schemata for activities in which the information is conveniently available. The information schema enables skilled teachers to deal with interactions between disparate goals and activities, a significant source of difficulty in complex domains. Theoretical analyses by Hayes-Roth and Hayes-Roth (1978) and by Stefik (1981) have shown how interactions can be taken into account in planning, either by recording relevant information on a kind of "cognitive blackboard" or with a system of "constraint posting" that uses knowledge of specific ways in which different activities are related. Processes described in these analyses permit information that is either expectedly or unexpectedly generated during actions to be saved, revised, and used for later actions.

Performance of Teaching

We hypothesize that the conduct of a lesson is based on an operational plan that we call an *agenda*. The agenda includes the traditional "lesson plan." It also includes activity structures and operational routines that are specific versions of schemata in the teacher's general knowledge base. The agenda also includes decision elements that permit continuous updating and revision of the agenda itself.

The duration of a lesson often corresponds to a class period of 50 min, but in self-contained classes, many lessons are shorter or longer. Within a lesson there are subunits such as presentation of the subject matter and activity elements. We refer to the main segments of a lesson as *activity structures*, using a concept that has been prevalent in sociology and the sociology of education for some time, especially in the work of Bossert (1981), Stodolsky (1983), and Berliner (Berliner, King, Rubin, & Fisher, 1981) and in a different form from that of Good, Grouws, & Ebmeier (1983).

The agenda for a mathematics lesson includes several global activity structures such as checking homework, presenting new material, getting problems worked at the board, having independent seatwork done, and so on. Along with general features including goals and termination conditions found in the schemata, the activity structures include components that are chosen by the teacher for the specific lesson material, such as concrete examples and materials to be used in explaining mathematical concepts and in getting student performance up to a desired level of proficiency.

For a particular structure to "work," supporting routines need to be available. Routines are small, socially scripted pieces of behavior that are known by both teachers and students. For example, a routine for distributing paper is often initiated by the teacher walking across the front row of the room with a pad of paper and giving several sheets to each child in the front row. The first child in each column then takes one piece and passes the rest back through the column. This routine provides a quick and efficient way of distributing paper, a requirement that arises in several activity structures. Verbal routines also exist in the form of choral patterns of response or turn taking without repeated explanation. Intellectual routines exist in the form of turn taking in solving a new type of problem. "Watch and listen" and "Now you try to figure it out" are the unspoken guides to such actions (Leinhardt, 1983; Leinhardt et al., in press).

Information that is important for decisions in some activity structures can be obtained easily during other activities, and skilled teachers take note of such information as part of their teaching performance. The activity of checking homework can be performed in a way that lets the teacher know who had difficulty and is therefore likely to lack understanding of a concept that is a prerequisite for learning later material. Skilled teachers also make use of an action that records which students had difficulty so that such information is available for later use.

According to this analysis, some important functions of planning and decision making are embedded in the performance of teaching a lesson. Thus, the agenda functions as a plan. Many items on the agenda are specified implicitly by the teacher's knowledge, rather than being worked out explicitly. Therefore, the conscious planning activity of teachers reflects only a small fraction of the planfulness that actually characterizes skilled teaching.

Skilled teaching requires decisions about whether to proceed with the next component of a lesson, based on students' readiness for new material and the likelihood that students will succeed in solving instructional problems, or involving selection of students to ask questions or give special help. For example, as a check on whether students understand and recall a relevant prerequisite vocabulary term or concept, a teacher may call on a weaker student because such a student is more likely than others to have misunderstood or failed to learn the concept. In our hypothesis, information needed for these decisions is obtained by skilled teachers in the process of conducting other activities. The information, therefore, is obtained as an incidental effect of satisfying other goals, rather than as a deliberate activity; however, it nonetheless provides the teacher with sensitive assessments of individual students' readiness and instructional needs.

Example of Segments

Having presented our hypothesis about the nature of teaching in general terms, we turn to a more detailed exploration of teaching. First, we lay out a series of *planning nets* for a sample of activity segments. These planning nets represent structures of actions and goals that are generated by the knowledge base that we hypothesize. The element that distinguishes this analysis from other analyses of educational events is that it combines easily

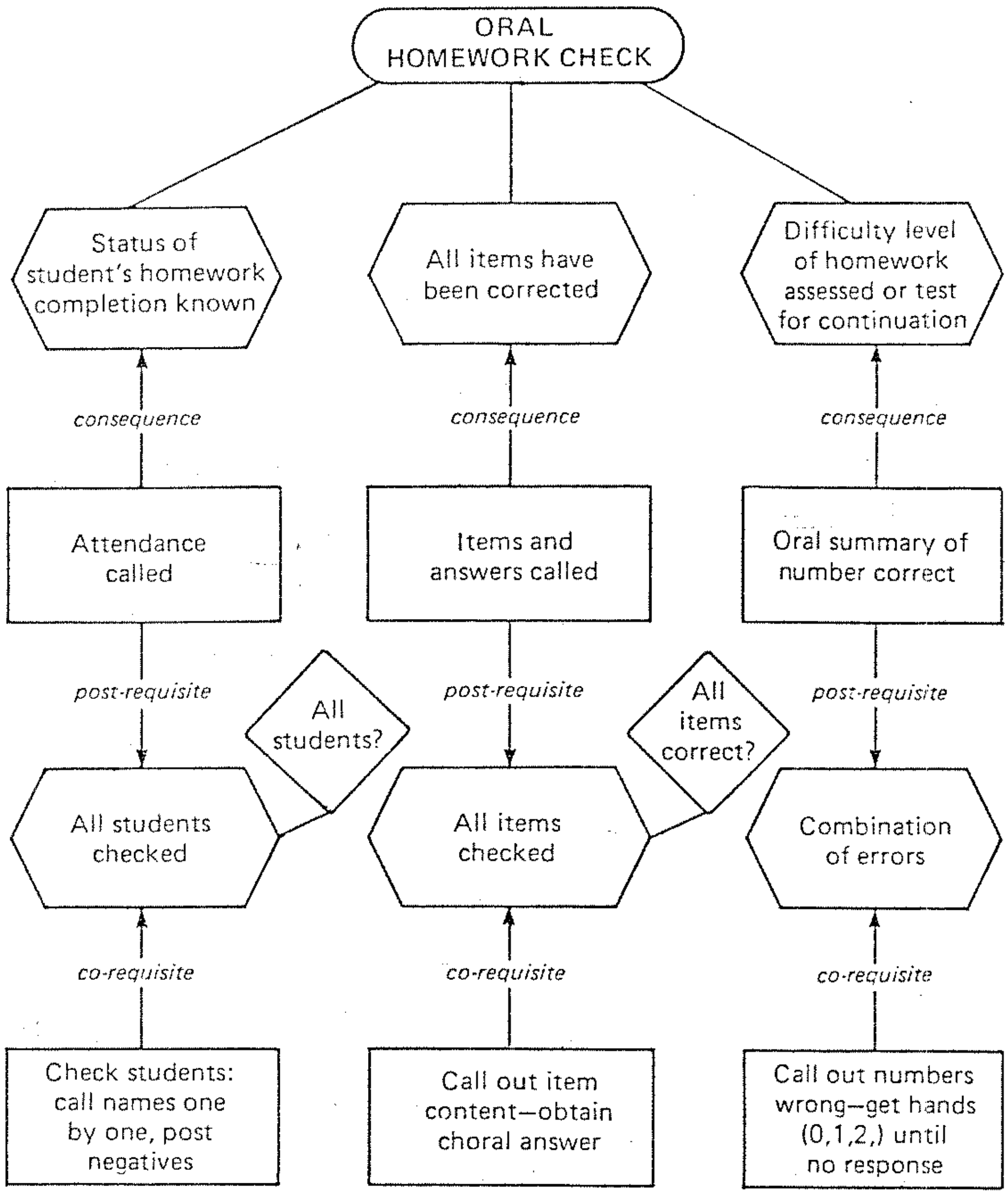

Figure 1. Planning net for oral homework check.

they do occur, the actions can have multiple effects, and poorly executed actions can have disruptive effects.

Figure 1 shows the planning net for an oral homework correction. The figure consists of a set of goals that are realized through a set of actions and other goals. Actions take place if the necessary prerequisites are satisfied, and they are completed or "exited" when the necessary postrequisites are achieved. Figure 1 shows the primary actions for homework in the context of goals and other actions. The top-level actions and their requisite conditions have already been described (attendance, oral-correction, oral-summary). The plan shows the series of goals that are the consequence of three rather simple actions: calling attendance and asking whether homework has been done or not; calling out items and obtaining their correct answers; and calling out numbers of items missed. By performing these actions the teacher places him- or herself in a position of knowing a great deal about the current knowledge level of the class, collectively and individually, and about difficulties that are likely to arise.

Figure 2 shows the first part of a presentation activity segment designed to communicate an algorithm. In presenting any segment of information to students, teachers need to determine that terminology to be used that has been covered in prior lessons is known. This goal is shown at the upper left of the figure and is accomplished by stating or reviewing all of the definitions. The teacher has two primary actions available for getting a definition stated. The actions are "student states definition" and "teacher states definition." If the teacher states the definition, she or he remains in control and is essentially going through the procedure observable activity elements with goals that are usually not explicitly described. The planning nets display examples of specific goals and actions that can be generated in actual performance with the knowledge base that we hypothesize.

In order for a teacher to function effectively, he or she must have an effective array of schemata that can be called on as the lesson progresses. Perhaps the most important schemata are those that support *presentation* of lessons. We hypothesize that there are several presentational schemata but that three are especially relevant: algorithmic, conceptual, and review. These include several common characteristics — a check for prerequisite knowledge states of students; a selection of the angle or approach of the lesson; a selection of exemplars; a monitor for student understanding and attention; and an exit for moving out of the presentation to the next element of the lesson. The algorithmic presentation must also contain knowledge for describing and performing the algorithm and for using whatever concrete representations will be included.

An action schema is a general representation of an action (at some level) that the individual can perform. The schema includes information that specifies one or more *consequences* of its action and *requisite conditions* that are required for the action to be performed. A *prerequisite* condition must be satisfied before performance of the action; a *corequisite* condition must be satisfied during performance of the action; and a *postrequisite* condition must be satisfied to complete the action. This representation of action schemata is based on Sacerdoti's (1977) formulation, with some additional features used by Greeno, Riley, and Gelman (1984) and by Smith and Greeno (1983). Planning begins with a general goal, for example, to teach the material in a specified unit of the course. The planner has general procedures, including search for an action schema with a consequence that matches a specified goal. When such a schema is found, its requisite conditions have to be satisfied to include that action in the plan. Conditions may be achieved on the basis of subject matter knowledge or by using some feature of the classroom setting. Otherwise, conditions must be satisfied by setting goals for further planning, including search for additional action schemata.

The activity segments that we present here are three that occur quite frequently in lessons and that have structures quite different from one another: homework correction, lesson presentation, and guided practice. Many other lesson segments are also used quite frequently: tutorial, drill, and testing, for example. The three we have analyzed were chosen for their frequency and instructional significance. Homework correction is an ideal example of how one rather small lesson component (it lasts 2–5 min and is rarely mentioned by teachers, student teachers, or texts) can help achieve multiple goals. Lesson presentation is a central activity of teaching. Guided practice represents the critical transition to independence on the part of students.

As a first example of action schemata used frequently in homework correcting, consider the actions called ATTENDANCE, ORAL-CORRECT, and ORAL-SUMMARY:

ATTENDANCE:
- consequence: homework status of all students is known
- postrequisite: all students are checked
- effect: students are monitored
- effect: students about whom information is lacking are noted

ORAL-CORRECTION:
- consequence: all items have been corrected
- corequisite: answers are made available
- postrequisite: all items are covered
- effect: items causing difficulty are known (i.e., those items that many miss)

ORAL-SUMMARY
- consequence: difficulty level of homework is known
- postrequisite: all possible error combinations are covered
- effect: children in difficulty are known (i.e., those with multiple errors)

As another example, consider two actions called STATE-DEFINITION and CALL-ON-STUDENT, used frequently in presentation and described as follows:

STATE-DEFINITION
- consequence: definition is stated
- effect: little time is used

CALL-ON-STUDENT
- prerequisite: student probably knows definition
- consequence: student responds
- effect: students attend
- effect: more time is saved

Related to the CALL-ON-STUDENT schema is some causal knowledge that when a student responds to a question, the correct answer may be given; the probability of this varies, of course.

The planner considers schemata whose consequences match its current goal. For example, STATE-DEFINITION and CALL-ON-STUDENT will be considered when the goal is to have a definition stated. STATE-DEFINITION can be used to achieve that goal directly, and it uses only a small amount of time. The goal can also be achieved by CALL-ON-STUDENT, and the probability of success depends on which student is chosen. One effect of using CALL-ON-STUDENT is to increase the attention of the students, and if the teacher has time and increased attention is desirable, she or he can choose this schema instead of STATE-DEFINITION.[1]

Correction of homework can be a rather minor aspect of a lesson. We include it here because of its relevance to other parts of the lesson and to demonstrate how a planning net can be interpreted. Homework can be corrected in many equally effective ways. It can be passed in and marked by the teacher and passed back; it can serve as a lengthy review, with students putting problems on the board and discussing them; or it can be a public exchange of problems and answers. Activities such as homework correction and others like it do not occur every day, but when

[1]Some additional executive functions are independent of the level of planning that we are describing. For example, teachers must select the specific content and approach before moving into a teaching plan. We hypothesize that while actually teaching, the teacher posts mental monitors that function throughout the lesson execution. These include maintaining attention, maintaining time flow, deciding whether to continue, watching for signals to abort the segment of the lesson (or in rare, but observed, cases the entire lesson), and posting stray pieces of student/lesson data. One can consider these as a series of questions that are addressed to the system on a regular basis: How are we doing on time (need to stretch or need to speed up?)? How are the weaker children doing? Is everyone "alive" or are they "dying" on me? We assume attention is given to these concerns from time to time and that information relevant to them is kept on a "cognitive blackboard" (Hayes-Roth & Hayes-Roth, 1978).

responds, the correctness of the student's statement has to be assessed. If it is correct, then the goal of having the definition presented has been met. If it is not correct, then decisions have to be made about whether time is available and whether other students are likely to present the information accurately. If time and another knowledgeable student are available, then another student can be called on. If time is not available or the teacher does not feel that another student can answer adequately, then the teacher cycles back up and uses the teacher statement.

The use of student action to achieve a teacher-based goal is an example of the dynamic nature of the classroom. When the teacher surrenders the control of actions to a student, she or he has altered the probability of the correct action's taking place from near 1 to less than 1. The selection of a student is based on some prior causal knowledge the teacher has that the desired action will probably take place, but the uncertainty requires a test.

Another goal of presentation is to have the algorithmic portion of a lesson presented. The set of actions that support the goal of presenting an algorithm or procedure are STATE-ALGORITHM and DEMONSTRATE-ALGORITHM. The planner will consider these actions when the goal is to present a new piece of mathematical procedure.

Figure 3 shows the planning net for the algorithm presentation portion of a lesson. At least two major actions can go on, either sequentially, simultaneously, or exclusively: (1) verbal description of the algorithmic procedures using an example or (2) demonstration of the algorithmic procedures. There can be demonstration without accompanying explicit verbal statements just as there can

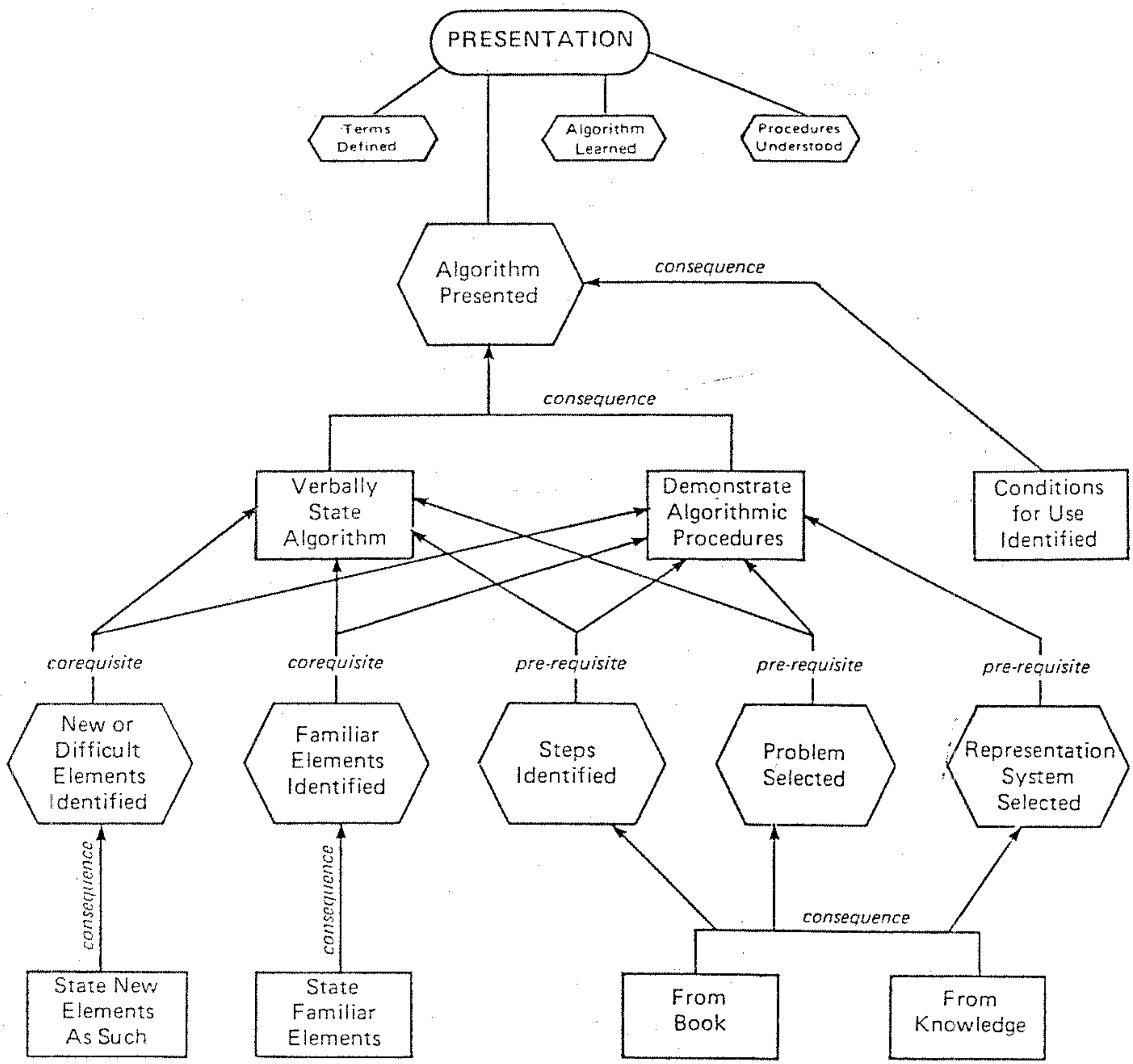

Figure 3. Planning net for presentation of algorithm.

of a lesson. There is no ambiguity or decision making required beyond that of presenting the correct term. The prerequisite is that the term is selected. The corequisite is that the students are attending. A consequence of stating the definition is that it tends to keep the lesson moving. It tends to be quicker than the alternative.

The second option of having a student state the definition has the advantage of student involvement. In order to have students define the terms, the students must be in a position to respond. Initially, students are in a position to listen or are attending or are presumed to be attending. The teacher has to engage in an action that alters that state from attending to responding. Depending on whether the teacher is calling for individual or choral response, the cues to change that state are calling a student's name or pausing significantly to get a choral response. If an individual student

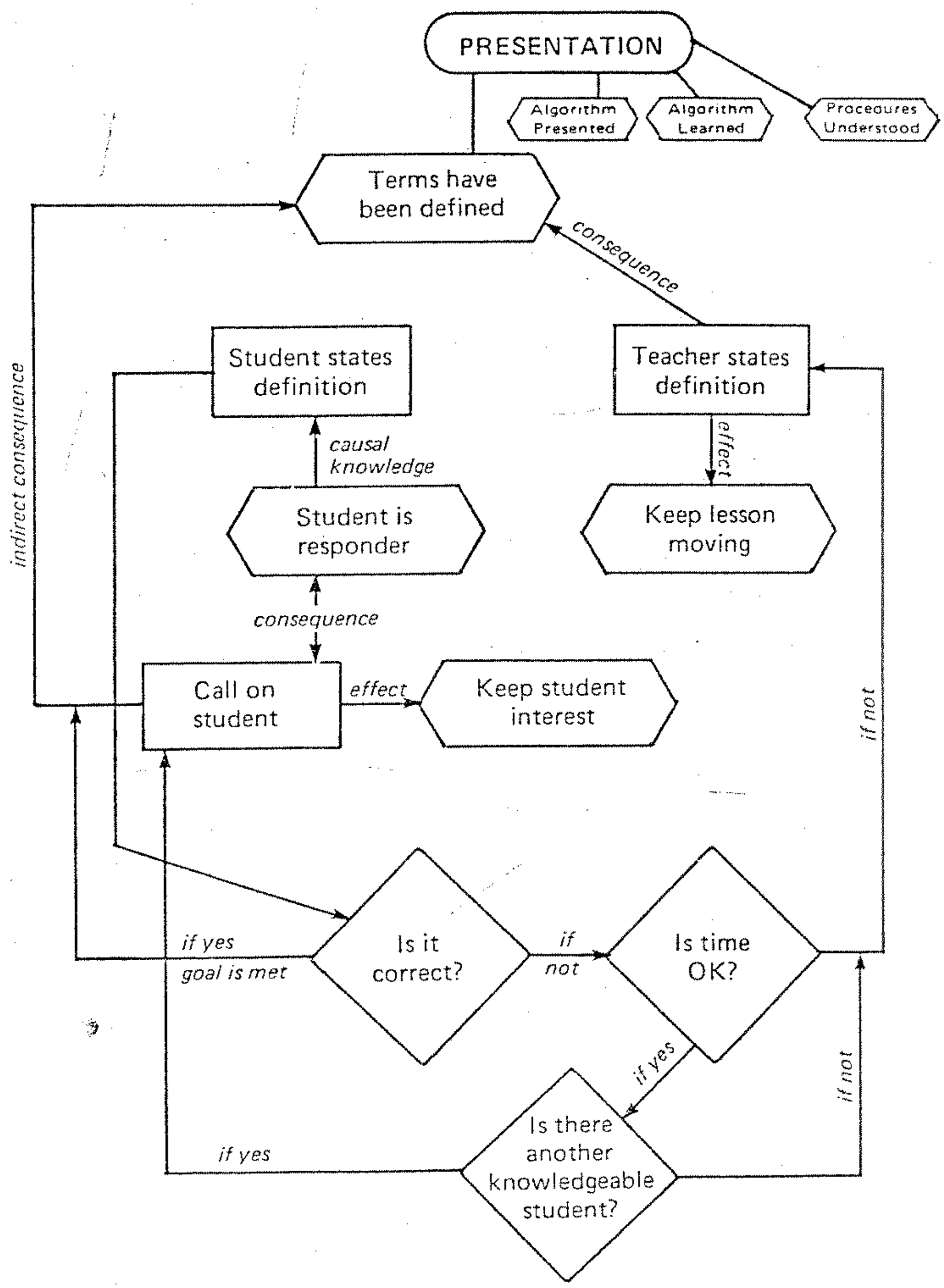

Figure 2. Planning net for definitions.

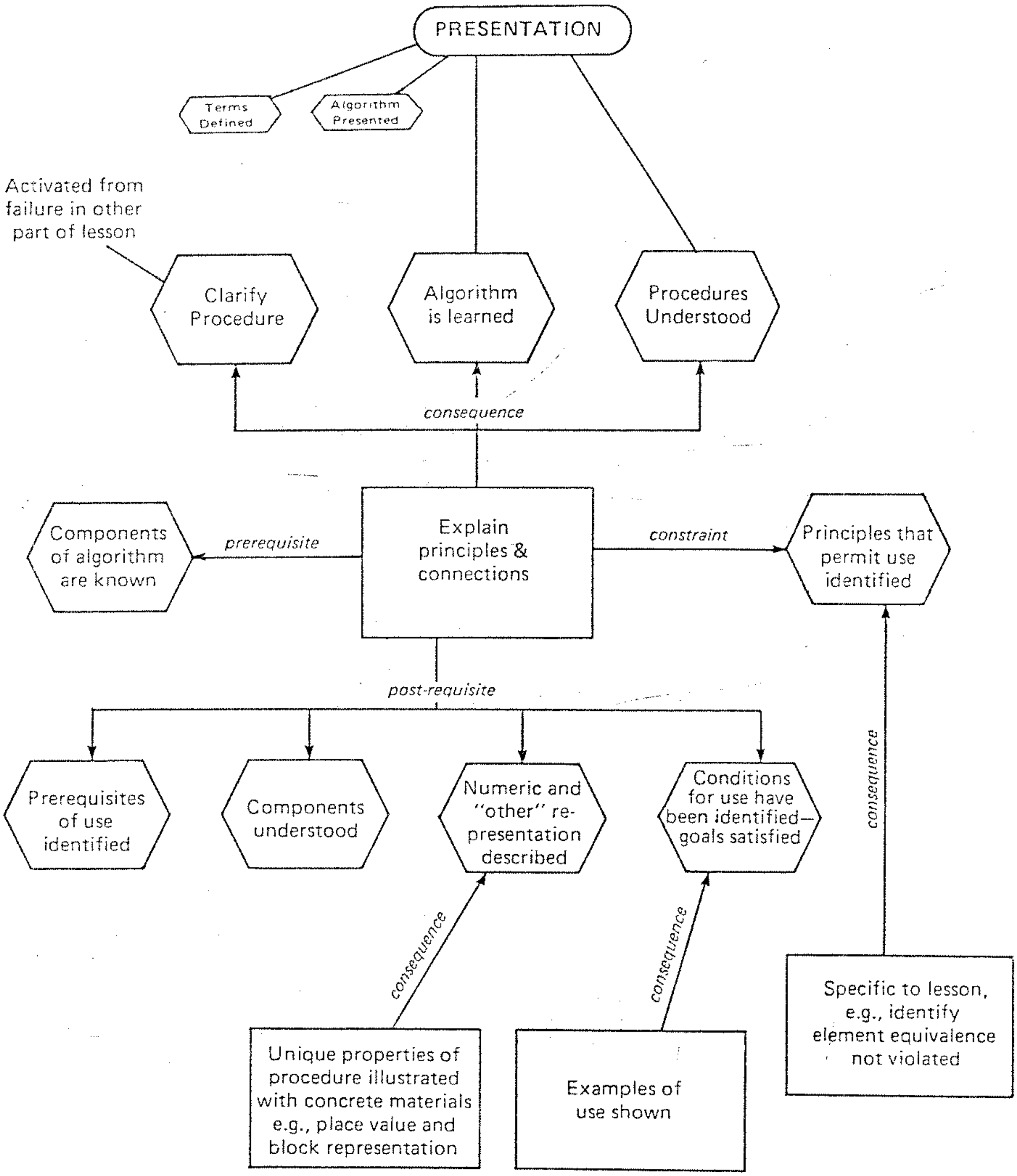

Figure 5. Planning for presentation for understanding of algorithm.

A portion of this information can come from the actions of having students at the board or having individuals recite. Finally, problems need to be selected that can be used for the re-presentation of the algorithm. It is possible under some conditions that a teacher will collapse the learning and presentation goals together.

A final action of presentation — explaining the algorithm — is shown in Figure 5. There are three possible goals: (a) to enhance learning, (b) to promote student understanding of procedures, or (c) to clarify individual or group confusion resulting from other actions. The action of explaining is related to the goal of under-be verbal description of the algorithmic procedure without a concomitant demonstration. The majority of algorithmic presentations, however, include both the verbal and the demonstrative portions. (Some reasons for this are discussed by Chaiklin, 1984.) In order to verbally describe the algorithm, the new or difficult elements must be identified. This can be done by presenting the new elements explicitly as such or by vocal emphasis. Another subgoal is to identify familiar elements, and this can be accomplished by stating that they are familiar. Prerequisites to verbally presenting or demonstrating the algorithm are identifying the steps of the algorithm and selecting problems. Identification of the steps of the algorithm can come from some general knowledge source or from a book. Constraints on this system are that the subskills are in place, the vocabulary is in place, and that one can maintain attention and maintain the pace.

Another goal of presentation is to have the algorithm learned (shown in Figure 4). The principle action for learning the algorithm is REHEARSE.

After defining terms and while presenting the elements of an algorithm, the teacher has the students rehearse. A postrequisite of rehearsal is that the algorithm is re-presented through several possible activities: board work, choral recitation, individual recitation, or by restatement. The first three of these actions have as a consequence that student attention is maintained. The actions for re-presenting the algorithm also require student selection and a testing of student accuracy like that shown for definitions in Figure 2. In addition to the accuracy tests for each type of student response, a test for the goal of learning the algorithm is necessary. Information for the test can be generated by learning the performance status of a range of students: strong, average, and weak.

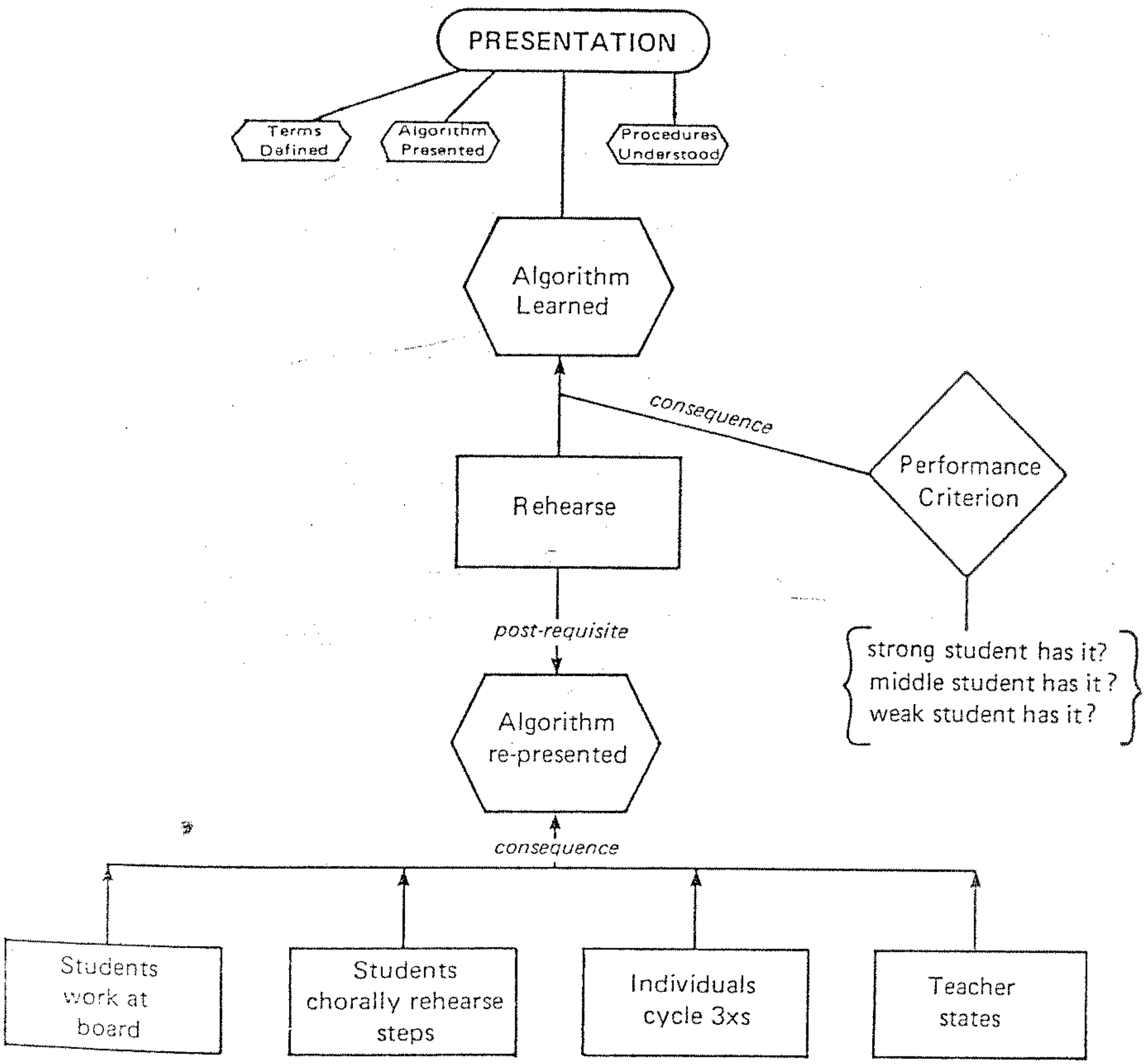

Figure 4. Planning net for learning algorithm.

categories are displayed in Table 1, which shows that the most frequently occurring categories were presentation, shared presentation, guided practice, monitored practice, and transition. Of the instructional segments (those other than transition), the bulk of the lessons consisted of first presenting or reviewing material, then moving into a dialogue with students in which new material was reviewed, and then practicing the new material in increasingly independent ways.

Figure 6 shows a set of parallel box plots for novices and experts for the four major categories. Box plots are rectangular schematic diagrams that identify the median, quartiles or hinges, and range points. The range points are the end points of lines called whiskers; the hinges are shown by the outer edge of the rectangle; and the median is shown by the inner vertical line. The most striking feature of Figure 6 is the difference in spread. The experts' behavior was more consistent over time than the novices'. This was true not only in terms of time, but also in terms of the content of these action segments. Although both the within and between variance were considerable, teachers were consistent in the key activities of presentation, shared presentation, and monitored and guided practice.

Table 1
Median Duration, Range, and N for Activity Structures Across Six Experts

Activity structure	Median (in min)	Range (in min)	N
Presentation and review	7	1–22	37
Shared presentation	11	3–38	46
Drill	4	1–30	21
Game drill	11.5	6–40	6
Homework	2	1–15	11
Guided practice	10	2–52	43
Monitored practice	20	4–53	50
Tutoring	7	2–41	19
Test	12	1–22	5
Transition	2	1–14	62

Note. Medial total length of classes was 41 min.

Analyses of Specific Teaching Episodes

We now describe several protocols of teaching episodes, with interpretations based on the hypotheses about knowledge struc-

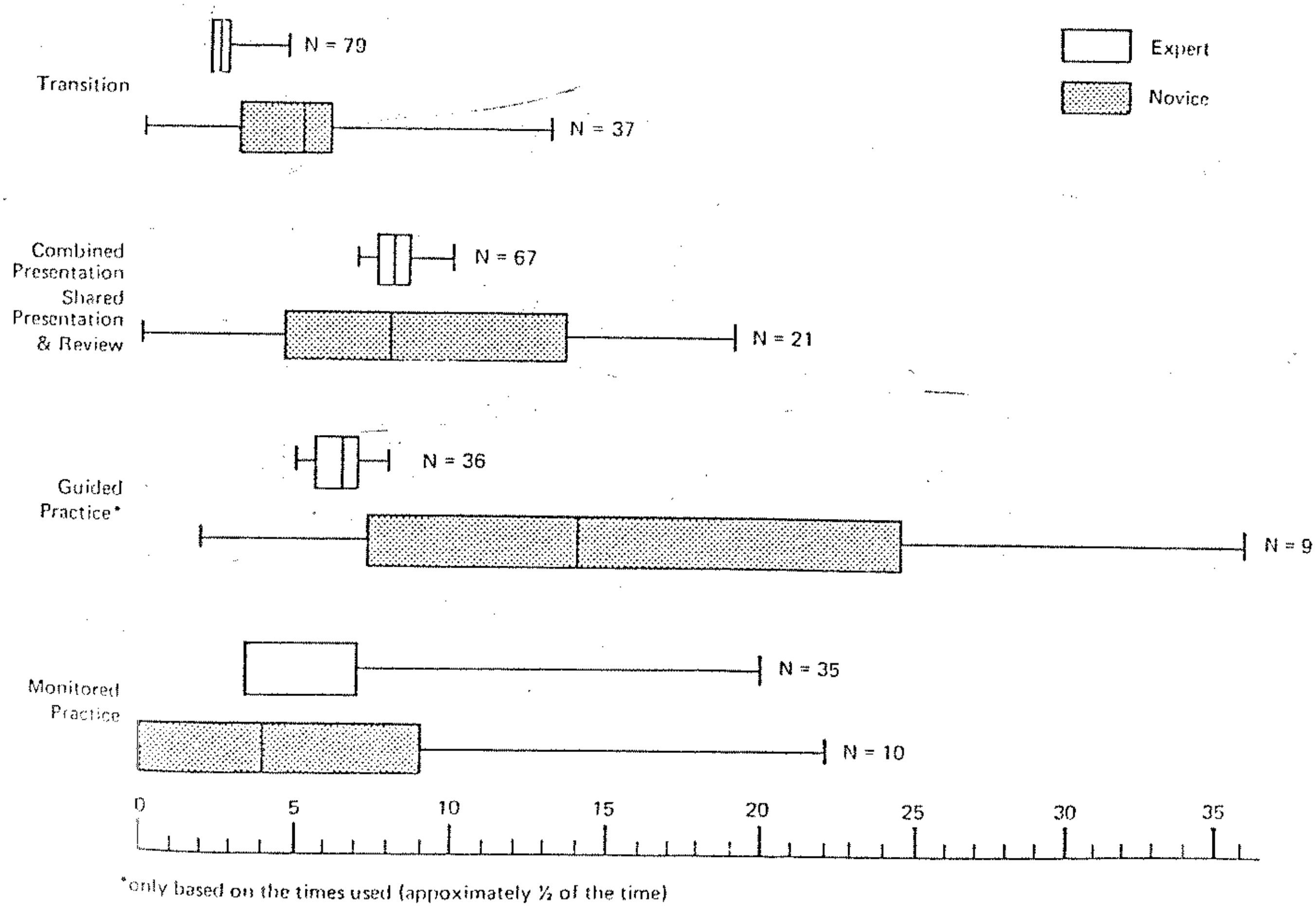

Figure 6. Box plots of activity structures for experts ($N = 4$) and novices ($N = 2$).

standing and can be set at any time during the review or presentation. Such a goal would emerge if and when student performance indicated confusion. Thus, if performance indicates confusion then one should explain rationales behind procedures. Three subgoals drive the explanation: (a) reviewing the numeric representation and another system (e.g., blocks, pictures) so that the unique properties of the procedure can be identified and the flexibility of seeing the procedure work in another way can be developed (this also can strengthen linkage to the other system); (b) identifying conditions of use, namely, what doing this procedure produces in terms of goal satisfaction; and (c) explicating constraints that the algorithm satisfies, for example, maintaining equivalence, use of the identity property, use of the order property, and so forth.

In summary, we hypothesize that teaching is a cognitive skill that has features such as an agenda or master plan that usefully assembles goals and actions in the service of instruction. The agenda serves to organize the action segments of a lesson. We further hypothesize that lessons have activity segments, each of which can be characterized by its own plan. These plans contain both the action schema discussed previously and the goals, termination conditions, and/or tests for completion. Routines are a particular type of action schema — namely, shared, scripted, low-level elements of cooperative behaviors that are automatized and are indicative of successful classrooms. The cognitive skill of teaching also contains a system of information acquisition and retrieval that permits useful information to be noted at one level and used at another. We turn next to examples of expert and novice teachers and examine our theory in light of their actual performance.

Observations of Teaching

We now describe a research project in which successful, experienced teachers and novice teachers were observed and in which their activities were interpreted using the framework described previously. The goal of the research was to elucidate the activity structures and routines of skilled teachers by (a) describing what they are, (b) analyzing their frequency and duration, (c) analyzing the functions that routines serve for the cognitive processes of teachers, and (d) contrasting the activity segments of novices and experts.

Method

Population

The population used in this study was a group of "expert" teachers and a group of novices. Experts were identified by reviewing the *growth* scores of students over a 5-year period and selecting the classrooms that appeared within the highest 15% of each grade. Classrooms in which the *final achievement* was in the highest 20% were then chosen from among the high-growth classes. Of the 15 teachers identified, 8 experts agreed to participate. All of the teachers taught in self-contained classrooms, and 2 taught an additional math section. The median class size was 28. Students in the classrooms came from families who ranged from lower class to lower middle class. One classroom was all white, two were all black, and two were integrated.

Novices were student teachers in their last semester of undergraduate training, chosen from a pool of 20 who were available. The 4 who were selected were considered to be the best students and were teaching fourth grade in two integrated middle-class schools. The most competent of the 4 was used for the detailed analysis presented here.

Data Collection and Analysis

Each teacher was observed during a 3½-month period. Observations included about one fourth of the mathematics classes the teachers taught during this period, nearly one tenth of the classes taught during the school year. The pattern of observation was as follows: (a) observation of three classes with open-ended notes; (b) 1 week of observation of continous classes, with an all-day observation taken once during the week; (c) 3 separate days of observation in which pre- and postinterviews were conducted that asked the teacher about his or her plans for that period; and (d) videotapes of three to five classes for which there were also preclass planning interviews and postclass interviews that included stimulated recall based on the videotapes of the classes. Further interviews with teachers about their own and their students' knowledge of mathematics were also conducted.

Two types of data were obtained: videotapes and transcriptions of notes and interviews. For each teacher, the notes were segmented into action records that listed durations, actions of student, action of teacher, and a name for the teacher's action. Each action was defined, and the definition was used as a basis for analyzing additional transcriptions or videotapes.

The total set of codable data for each teacher was used, and medians and ranges of time spent in each activity were calculated. For two experts and one novice we selected one tape for a more detailed interpretation of goals, activity structures, and routines. These tapes were selected for recording quality and teachers' comfort with the session. In analyzing these tapes, we also drew on information from the stimulated recalls, interviews, and other transcribed discussions with the teachers.

Results

Activity Structures

Ten categories[2] were used to describe the actions of expert teachers. The medians and ranges of durations for each of the 10

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[2]*Presentation* refers to a teacher's uninterrupted explanation of new or very recently learned material while students listen. In *shared presentation*, the teacher presented material, usually through questioning or with the help of one or more students orally or at the board.

Guided practice is a form of seatwork in which students work on presented problems at desks or at the board with guidance from the teacher. Students work on five or fewer problems at a time. The teacher keeps up a fairly continous explanation of the problem and usually gives immediate feedback to the group on the answers to problems. *Monitored practice* is the more traditional seatwork where the teacher moves about the room checking and tutoring while students work.

Homework refers to checking and collecting homework or seatwork. Most teachers took care of homework either at the beginning or the end of the day or by a pass-in/check/file system.

Drill is timed rehearsal of facts by students, either orally, in writing, or at the board, and is usually paced by the teacher. *Game drill* is timed by virtue of a race between groups or individuals. It involves the rehearsal of facts by students in a loud, usually public atmosphere.

Tutorials are extended presentations to a few students (2–5) while other students are working either at the board or at their seats.

Transition refers to a change from one activity to another. The teacher usually lists several actions and the students execute them.

Constraints: Reinforce doing homework
Keep pace moving
Keep attention
Watch for Bryan and Cammy

Expert

Goal 1 Homework check

Subgoal 1A – Who has it? Time ~ 30 seconds.

action: T call attendance – *Cue
S say yes or put name on board

function: Monitors

outcome: Knowledge of who has not done homework – carry forward

Subgoal 1B – Correct work. Time 106 seconds

action: T calls out problems
Ss call out answers – correcting pencils

function: Paces, both groups have information, keep attention

Interruption – "How many reduced it to 1/6?"

Subgoal 1C – How many got it correct? Time 22 seconds

action: T calls number perfect then number incorrect (2,3,4 . . .)
Ss raise hands

function: Monitors, summarizes

outcome: Students who got several wrong noted and carried forward

Conclusion Cue: *Pass to the front, put your books in your desk.

Figure 7. Expert homework.

mained constant over many settings (out of a total of 18 observations on homework check), the actions and routines varied considerably. Sometimes homework was corrected by having individuals go to the board, each one working out a problem while the rest of the group monitored. At other times, papers were traded and corrected; and at still other times, work was simply passed in. Variety, itself, was valued and often drove a change in approach, but time and depth of knowledge required also constrained the options.

In contrast, a novice teacher doing the homework check activity behaved differently. Figure 8 shows the homework check activity for one novice. It was an extended activity (6 min) in which the goal was reached somewhat indirectly and without the type of teacher control present in the previous examples. The homework activity included two subgoals: first, identifying who did the homework and, second, orally correcting the problems. For the first subgoal, the novice, Twain, stood up at the front of the room and asked, "Who doesn't have their homework?" The students did one of the following: stayed seated and held up completed work; stood up, walked to the teacher, and said either they had it or did not have it; or called out from their seats that they did not have it. The novice teacher responded that homework is important and there were no acceptable excuses, and marked on a posted sheet whether work was completed or not. She included no summary action; thus, she did not have accurate information about the homework status of everyone (that is, the check sheet was not systematically reviewed). The informational effects of the action system were not available as they were for the experts. The novice used a less effective question, did not have a routine to obtain the information, and did not maintain control of the flow of information. The students, in an attempt to comply with the somewhat unclear request, responded in a variety of confusing ways. Not only was her attempt at accomplishing the first subgoal time-consuming (it took 85 s), but Twain was also unable to retain the information in memory to carry it forward and her information was incomplete, as will be seen later. She apparently terminated the action because of time constraints and the press of the next subgoal rather than because the goal was met.

tures that we presented in the first section of the article.[3] The episodes come from a lesson on mixed numbers taught by an expert, Ms. Longbranch, a lesson on equivalent fractions taught by another expert, Ms. Wall, and a lesson on multiplication taught by a novice, Ms. Twain. Longbranch's lesson is presented in considerable detail, and the complete protocol is discussed. The complete protocol for Wall's lesson also is presented, but we discuss it more briefly. Excerpts from two of Twain's lessons are discussed in order to highlight contrasts between expert and novice performance.

Longbranch's lesson began with homework correction; then there was a brief review of terms followed by a shared presentation of how to change a mixed number to a fraction. The shared presentation was continued using a public practice format for a considerable part of the class, with several groups of children called to the board and returning to their seats. Guided practice was started with some children at their desks while others worked at the board. The class ended with enrichment worksheets being done. Twain's lesson started with correction of homework and a brief review of the algorithm to be used. The rest of the lesson was devoted to a game drill of "concentration" in which each child had at least two chances to practice using the algorithm to determine whether the pairs of fractions they uncovered were equivalent.

Homework Check

The first clear objective in Longbranch's lesson was to get the homework corrected and handed in. Within this goal there were three subgoals: to establish who did or did not do their work (those who did not recorded their names on the board); to have the work corrected; and to assess the general success rate.

Figure 7 shows the actions related to achieving the first goal. The actions are listed chronologically down the chart. The teacher gave the cue, "Ok, set 43." Attendance was rapidly called: each child answered yes or wrote their name on the blackboard; time to complete was approximately 30 s. The routine was well rehearsed and universally known. The action provided information and exerted a monitoring and public control function. An outcome was that the teacher knew who had not done the work.

The second subgoal was to correct the homework. The students took colored pencils out and responded chorally with the correct answer, a fraction in lowest terms. As the teacher called the problem, "1/12 + 1/12," they responded, "2/12 or 1/6." Time to complete was 106 s. The teacher's calling out of the problem served the function of pacing the class through and reinforcing the pairing of problem and answer. A second function was that it let the teacher note if any of the items produced problems for the group as a whole, as, for example, when multiple answers were shouted. Thus, at one point in the lesson through the use of two of the three homework checking routines, the teacher knew which children she did not know about (namely, the ones who didn't do their homework) and which problems, if any, created difficulties.

The last subgoal was to discover which of the children had difficulty in general with the assignment. This was accomplished in 30 s by calling out the number of problems missed and having children raise their hands. The homework (or class work) activity structure accomplished a lot in a little time and produced information that could be easily carried forward into the rest of the lesson. The routines used were attendance response, choral response, and hand raising. The teacher thus reduced the amount of potential processing and kept a simple component of the lesson simple.

Another expert lesson, given by Wall, was on equivalent fractions. This lesson also started with the correction of homework and a brief review of an algorithm. The rest of the class was devoted to game drill of "concentration" in which each child had at least two chances to practice using the algorithm to determine if the fractions uncovered were equivalent. As in the first expert's lesson, the first goal of this lesson was to get the homework corrected. The subgoals were also similar: determining completion and the success rate.

The actions in this lesson were slightly different from those of Longbranch. Wall began by telling the students to get out their homework. She then gave a misinterpreted cue of "Ted?" and got the response "Here," obviously calling up the routine for attendance. Wall corrected the routine by immediately saying, "Do you have it?" She got the correct response and continued calling attendance. She marked the responses in a book she was holding. This segment of the homework check was completed in 55 s.

The second action was, as in the first lesson, to correct the homework. The teacher called out an individual child's name and the problem. The child responded with the answer. During the 165 s it took to check the problems, Wall asked, "Checking work?" She paced the work by calling out the problem and monitored the class's responses by her reminder to "check work." The calling of individual children's names allowed her to reach her informational subgoal of determining which children had difficulty with the work through a sampling strategy. Although this action did not provide as complete a sampling as Longbranch's, it is interesting to note that it was the three children Wall had described on a separate occasion several months earlier as "daydreamers" who missed the homework problems.

The last action was to assess the success rate of the class. Wall did this by asking, "All right?" and made a quick scan of the room to determine whose hands were raised. This took 5 s and, in conjunction with the information obtained during the homework correction, gave the teacher information she felt she would need later.

Although the goal and subgoals of correcting homework re-

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[3]Our interpretations of these episodes organize the teachers' actions into activity structures. We hypothesize goals and subgoals associated with the activity structures and their component activities. Because we assume that performance is often controlled by a simple agenda, the goals of many action sequences are completion of the actions involved. Goals to obtain information may be achieved as incidental effects of the performance of activities; the action sequences include the recording of such information when it is obtained. In our analysis of each activity structure, we traced the action chains and then hypothesized the basic objectives, goals, and subgoals that drove the activities. For each subgoal, the actions used to accomplish it were identified and the functions and/or outcomes were reported. A function is the result of an action; it is not identical to the goal or subgoal but may be relevant to satisfying a constraint or another overriding goal. The basic goals for the lesson do not stand alone, but both receive and produce products from other activity structures. An outcome or product is listed only if the consequence of an action produces something that must be carried forward into another goal or subgoal.

correction had the effect of informing them about problematic items unambiguously. For the novice, the information that an item was failed could be attributed to the responding student's inability to do the item mentally or to its general difficulty. The novice also showed no schema such as oral-summary and no goal surrounding homework difficulty, whereas both experts used such a schema. In terms of Figure 1, experts gave evidence of meeting all of the top-level goals described and showed considerable consistency in their use of action schemata. The novice showed no use of constraints in terms of meeting lower level goals in order to accomplish the basic objective. Thus, attendance was incomplete and there was no assessment of difficulty.

Presentation

Returning to Longbranch's lesson, the second goal was to present the topic of the lesson. For this class, the presentation and shared presentation activity structures were always used. Lesson presentation of the new material and mixed numbers is outlined in Figure 9. There were three subgoals: The first was to review the labels (vocabulary) needed; the second was to present the rules for the algorithm; and the third was to demonstrate the algorithm. Overlaid on these three subgoals were several systems of constraints that themselves helped to construct the solution: Keep the lesson moving,[4] get through the task,[5] call on different children,[6] watch for the stragglers and help them,[7] keep interest and action up,[8] and do not embarrass children.

To review the labels, the teacher asked for a definition. She selected one of the weakest children, Cammy, to answer. This was both to encourage Cammy and to do a bottom-level check — if a weak student could get it, the lesson could move rapidly. Cammy did not get the definition, and her failure produced another subgoal (2A1 in Figure 9), which was to check on her for the rest of the lesson. The teacher then moved to one of her strongest students for the definition — she also failed. Longbranch tried again with a middle-level student — he failed. She then called on a top child, who was correct; she repeated the definition after the student; and she had the class rehearse it chorally.

In the time constraint system, Longbranch was behind; and in terms of Figure 2, a teacher would now suppress the goal of keeping interest and move to that of keeping the lesson moving. For the second subgoal of the presentation, the definition of how to change mixed numbers to fractions, Longbranch felt she must move ahead, so she increased the pace but still tried to maintain involvement. She did this by having a choral reading of the rule from the rule cards at the front of the board. So, within 1½ min, she had reviewed the definitions, introduced an algorithm, and rehearsed it. (It should be noted that the prior lesson involved extensive "conceptual" work drawing representations of mixed numbers and talking about 1½ of a sandwich and ⅔ of a sandwich, etc.) Longbranch was then ready to use a routine of public practice in which a problem would be put on the board and a child would be called on to guide the teacher orally through the operation. Longbranch shared control slightly by permitting volunteers but called on one child at a time to do each of the three steps of the algorithm.

The first problem (Subgoal 2C in Figure 9) was 2½, a relatively easy problem. A child (middle level) was called on to perform a part of the algorithm (multiply the whole number by the denominator), and then the teacher followed the rule for the second step while the student dictated to her (add the numerator). These actions were carefully watched by the students; it was the first real demonstration of the algorithm, and interest may have been raised by watching a student tell the teacher what to do. At the third part of the algorithm, Longbranch asked for the answer to "keep the same denominator" and both 2 and 4 were shouted out by the entire class. This was an interesting failure in routine. Longbranch usually gave a problem, then called a name. When a name was not called, a choral answer was usually expected. In this case, Longbranch meant to continue with the same child, but the time lapse had been too long. She instead got a choral answer, which she interpreted as shouting out. She pulled the children together by telling them to sit up, put their pencils down, and not call out. The mutual misunderstanding was not recognized by the teacher (either when it occurred or later, when she viewed the tape), who simply saw the event as one in which she was trying to keep the children in control. ("And I like, as you have seen so far, I like order in my room. I can't stand that when they start all hollering out.") The second problem given to the students was 3⅗, which was assigned to a top-level child. He went through all the steps smoothly, thus publicly rehearsing the algorithm. To check how the lesson had been understood, she called on the weakest child (from Goal 2A1) and rehearsed the steps for changing 2¾ to an improper fraction. As the child gave the answers, Longbranch wrote the answers on the board. The actions produced a third example on the board, rehearsal of the algorithm, and a check of the weakest child, who was by then caught up. The teacher was

[4]Ms. Longbranch's concern about keeping the lesson moving is exemplified in the following excerpts. Interviewer: "What are the advantages of using choral check that you did for homework and for this?" Longbranch: "It's quick. It's very quick" (12/14/81, lines 401–403). "It seems the way I have math scheduled I only have that 40 minutes so I really have to know what I'm doing. I have to have my 40 minutes organized" (11/19/81, lines 201–205). "My math is 40 minutes . . . I can never drag math out for a couple of extra minutes (1/06/82, lines 244–245).

[5]Ms. Longbranch's underlying constraint of getting through the task is expressed in this quote (12/03/81, lines 342–347): "I don't have this written down anywhere, but in my mind, I have it. I'm going to be finished with fractions before Christmas. I have to be, you know, to get on. So I'll just pace myself now so that I will get finished."

[6]Ms. Longbranch tried to call on different children: "Everyone doesn't get to the board everyday. But most of them do" (1/06/82, lines 291–292). "I think I was trying to get all the children to the board that I thought would have any difficulty at all (12/14/81, lines 151–153).

[7]One important concern of Ms. Longbranch was to watch for stragglers and to give them additional help: "I can tell (the ones that have trouble), they're always the last ones to stand up. So I know they need special attention" (11/24/81, lines 38–41). "But usually the ones who have trouble will get to the board that day. The better ones will get turns, you know, every day, or three" (12/11/81, lines 447–451). "Then when you see the same person is always the last one getting up, well you know he or she is really having a tough time of it" (12/14/81, lines 358–361).

[8]Ms. Longbranch is operating within the constraint of keeping the children interested and action moving: "There's no specific reason why I have them stand — just to keep them moving" (1/06/82, lines 462–464). "I feel like if I don't have them keep moving constantly, or doing something constantly, their attention span, I don't care how good they are, it just floats away" (1/06/82, lines 464–466).

Constraints: Reinforce doing homework
Call on student
Who rarely volunteers

Novice

Goal 1 Homework Check

Subgoal 1A — Who doesn't have it — 85 seconds

action: T mark names on sheet at board

function: Monitor homework

outcome: Inadequate information about homework completion

Subgoal 1B — Correct work — 275 seconds

action: T calls out problem number
Gives set of problems or 1 problem to individual child
Stops calling out problem number

Interruption: Child answering does not have homework

S gives answers
Raise hand to volunteer

function: Moves in and out of pacing, information

outcome: Learns another child does not have homework

Conclusion Cue: *Clear desks

Figure 8. Novice homework.

The second goal was to correct the problems. This could have been done as the experts did it or by the teacher's collecting the work, correcting it, and returning it. Twain chose to call on students to give the correct answers (an action experts do use). She called out a set of problem numbers (1–10) and assigned a child to call out the answers as she called the problem number. The student slowly called out the answers in order. (The first child chosen was the lowest in the class, did not have her work done, and was doing the problems in her head). Thus, for the first 10 problem answers, the teacher lost control of pace *and* correctness of answer; however, it was only when the child failed on the sixth problem that Twain realized the student had not done her homework. (To get to the seventh problem took 105 s.) Twain then called on four separate children, each of whom gave the answer to one problem. The rest of the class was checking the work at their desks. Twain then picked her main "troublemaker" to do the next block of 10. The rationale that she gave later for choosing that child was that it was the first time the child had volunteered for anything. He missed one problem, but then continued, going through 10 problems in 70 s. The last child chosen went through the sequence quickly, but the sound of the child saying the problem number and answer next to each other was confusing (e.g., 24, 27; 25, 64).

The novice teacher clearly had the beginning of a strategy for getting homework checked. First, she did it. Second, she realized that she should have some structure and that time was a constraint. During each cycle, she started by having the child pace it and then she took over the pacing.

In the homework check segment of a lesson, a general goal was to get the homework corrected. Both experts activated similar schemata: attendance, oral-correction, and oral-summary. Longbranch and Wall differed slightly in the *actions* they used for oral-correction — one used choral responses, the other used individual responses. Both experts operated within similar constraints — to move quickly, to get all items corrected, and to know the approximate status of all students. The novice, on the other hand, did not have an attendance schema. Therefore, when the goal of assessing the homework status of students was recognized, she had to construct a set of actions that would satisfy it. The action of calling out "Who doesn't have their homework?" did not carry as a postrequisite that the status of all students was checked. Therefore, the novice ended the action prior to satisfying that condition. This, in turn, did not produce the effect of her knowing about the students, knowledge that the experts were able to secure. The failure to have the postrequisite also influenced the "effect" of the second schema used, oral-correction. For the experts, oral-

Constraints: Keep lesson moving
Complete task
Call on different children
Watch for stragglers
Keep up interest
Do not embarrass child

Expert

Goal 2 Presentation – Time 4½ minutes

- Subgoal 2A: Define a mixed number
  - action: T asks for a definition; Weak child is selected – fails
  - function: Involves students, Check on first child
  - outcome: Goal 2A1 – Check on Cammy
  - action: T calls on Tara; Child fails – confused
  - action: T calls on Chuck; Child fails – confused
  - action: Trish called on – gets it . . . T repeats definition, writes 2½ on board; Ss choral repeat
  - function: Get definition across; Don't waste time
  - Outcome: Time is lost – make it up; Goal 2A2
- Subgoal 2B: Define operation of changing a fraction to a mixed number
  - action: Teacher leads choral reading of rule
  - function: Clearly state algorithm, sacrifice student involvement for time
  - outcome: Time is caught up – goal 2A2 is met
- Subgoal 2C: Demonstrate rules: Select student, select problem – 1st iteration
  - Problem 1 – 2½
  - action: T puts 2½ on board, says rule – part 1 – calls on strong student, Tom; Ss misspeaks but says it correctly; T executes
  - function: T controls fit between rule and action and involves students
  - action: T says rule – part 2 – calls same student; Ss adds numerator, states answer; T executes
  - function: Same
  - action: T says rule – part 3 – and pauses; Ss chorally respond, in part incorrectly
- Interruption: Teacher calls to order and reprimands
  - function: Keep students obedient
- Subgoal 2C: Demonstrate rules: 2nd iteration
  - Problem 2 – 3 2/5
  - action: T puts problem on board 3 2/5; Calls on middle child (Emmett); Ss says rules and executes; T writes, pacing through each step
  - function: 2nd clean demonstration, mid level check, more independence
  - outcome: Success means can try on a lower student
- Subgoal 2C: Demonstrate rules: 3rd iteration
  - Problem 3 – 2 3/4
  - action: T puts problem on board; Calls on Cammy; T calls for rule (step by step); Cammy executes; T writes reinforces last step
  - function: Check weakest child, check for success of rule presentation
  - outcome: Success – move on

Figure 9. Expert presentation.

then ready to begin public practice on the blackboard with groups of students. Longbranch completed the demonstration portion of the lesson and went into the next segment, *public practice*. The students then rehearsed the algorithm for changing mixed numbers to fractions.

Goal 3 is summarized in Figure 10. The objective was to have

Expert

Goal 3 Public practice: Time 4½ minutes
Rehearse algorithm – 2 cycles Select Problem
Select Students
Orchestrate

Subgoal 3A: Set up board
action: T selects six students by name
T assigns to boards
T selects problem – 3 1/3
T asks for definition of type of number
Ss choral response
Ss at board do problem
T respond: walks through problem with child at the board
function: Fun, public rehearsal

Subgoal 3B: Monitor seated students (cycles) in parallel
action: T watch students to see if paying attention
Interruption – catches a student commenting to one at the board – assigns him to the board, too
function: Keep seated attending, punish inappropriate behavior
action: T select 2nd problem – 5 2/6
T calls on punished child to perform
S makes minor error
T does problem publically and corrects
*erase be seated
Call wave two
function: Public rehearsal and public chastisement

Subgoal 3C, 2A and 2B: Move to second cycle, rehearse
action: T *"Erase be seated", calls names to go to board
Group 1 sits
Group 2 goes to board – Keeps Bryan
T calls 4 1/2
(2A): T – to 2A1 – "What kind of number?" to Cammy, seated
S gives answer – slowly with prompts
(3C & 2B): T to another – (Tom at board) How do we change
S gives algorithm, and answer
T repeats answer
Ss do at board – Teacher corrects
function: Keep pace moving, keep action going, rehearse lesson topic
outcomes: Changed groups, algorithm is firm, can change to practice
action: T says – 6 3/5
Calls on seated to define steps
Continues oral problem solution
Ss at board do problem

Alright, erase, be seated

Figure 10. Expert public practice.

Novice

Transition is first followed by explanation of video equipment

Goal 1 Presentation – Time 3½ minutes

Subgoal 1A – Introduce multiplication by arousing interest, giving terms

- action: T directs attention to board
  Calls for choral response
  S few respond
- function: Involve students (fail)
- action: T reminds them of word problems several days earlier
  Calls for choral affirmation
  S no response
  T "Am I talking to myself?"
- function: Remind students of other lesson,
  Reintroduce problem, motivate students
- action: T prepare to hand out chips
  Changes mind
- outcome: Do not change to another subgoal

Subgoal 1B – Define terms in multiplication

- action: T directs attention to board
  Calls for choral response
  S several students respond

Interruption: T catches students looking around – "Get your eyes up here".

- function: Keep attention

Subgoal 1C – Demonstrate importance

- action: T shows them speed they need when doing times tables
  S complains she will forget tables
  T refuses to accept complaint that they will forget
- function: Encourage students to learn tables (partial success)
  Present level of competency beyond students
- outcome: Distracting argument
  Time lost
  Thread lost

Figure 11. Novice presentation.

guided practice. Thus, she seemed to lack both major goals for presentation as well as automaticity of action.

The second goal that we hypothesized was to present an algorithm (see Figure 3). Both experts did this. Longbranch presented the algorithm by reading with the class a verbal list of steps and then linking each action in the list to an action with numerals. Wall, who presented the second lesson on reducing fractions, prompted a verbal chain and asked for individual and choral responses in going through the steps of the first problem. Both experts used actions of verbally stating and demonstrating; both public practice at the blackboard. The action helped to meet the larger goal of going through a lesson and getting material learned, similar to the goals in Figure 4. The activity structure was still part of a shared presentation because the particular event involved only teacher-generated problems, not dittos or books. The routines were assigning to the board, student monitoring of board performance, and explanation of answers. The first action was to call students to the board by calling names of children. Before the children reached the board, the problem 3⅓ was called out. At that moment, Longbranch had to shift attention from the six children she had assigned to boardwork to those that were seated. She continuously looked for signs of restlessness, confusion, or inattentiveness — those at the board were under public control and needed less attention than the others. The students at the board wrote their solutions to the problem, and one child was called on to solve the problem orally, thus rehearsing the algorithm. While Longbranch watched the seated group and tutored, she saw Emmett make a comment to one child at the board. Longbranch assumed it was a negative comment and sent Emmett to the board as a reprimand. After the 3⅓ problem was finished, the teacher asked, "Everybody else correct? Erase? Put 5⅚. Emmett, you tell us this time. What are you going to do?" Emmett forgot to add the numerator, and his failure produced a "seeee" from the teacher. Longbranch had thus constructed a win/win situation. If Emmett did not get it, she could point out his error; if he did, she could rehearse the correct answer.

To move to the second cycle, Longbranch called for the students to erase and be seated; identified the second group, retaining Bryan, a weak student; called out the new problem, 4½, and checked with Cammy to define the type of problems (as mixed numbers; Goal 2A1). In one breath, she had shifted almost half of the class around, checked on a goal carried forward, given special attention to a child who needed it, and made progress toward completing her goal. With the second group of students, she reviewed the rules and got an answer from a seated child to retain attention. The activity was completed by saying, "Erase, be seated."

The second expert, Wall, used her presentation slot for a partial review of material introduced in the previous lessons — reducing fractions. She reviewed the algorithm of finding factors to help reduce the fraction. Wall used a shared presentation for the review. To pace the lesson, she wrote six fractions on the board (3/6, 6/16, 10/15, 2/16, 4/12, 12/15). She called on a top-level student to read the fraction. She gave them a cue from a previous lesson: "Ask the first question." The children gave her a choral response, "Is 3 a factor of 6?" She then asked Kali, a middle-level child, to identify the next step; and when Kali failed, Wall immediately called on a consistently top-level child, Aaron, who gave the right answer. The class then solved the problem chorally. She called for an individual response on the second fraction, got a choral response, and promptly regained her control by loudly repeating the child's name. The class went through the remaining five fractions using a mixture of individual and choral responses. Each problem was stated, "the question" was asked, and it was answered; if the numerator was not a factor of the denominator, the factors were listed and the largest common one was chosen, tested, and then used. The teacher checked on the three children who missed homework problems and all of them were able to answer correctly.

Wall ended her lesson with a game drill activity in which the children practiced using the algorithm by deciding if the fractions on two cards they turned over were equivalent. She described the game, set the rules, and then practiced by turning over two cards for the class to determine chorally if they were equivalent. Four teams were set up. The game proceeded with each child turning over two cards, writing the fractions on the board, and then orally going through the steps.

The novice's presentation shown in Figure 11 was chosen from a lesson different from that of the homework check in order to have an example of a cohesive presentation. This presentation did not proceed with the same fluidity as either of the experts'. The novice, Twain, introduced the concept of multiplication although the students already knew their multiplication tables through at least the fours. She started with the subgoal of arousing interest. Her actions were to (a) tell the students that this was so important that if they missed it, they would be lost for the rest of the year; (b) cue students to chorally read the word *multiplication* — only a few participated; and (c) describe at length some word problems the students wrote out several days earlier, one of which required repeated addition. These actions did not achieve the subgoal of arousing interest very well. The students responded to the three verbal actions, each one of which ended with a type of rhetorical question, with decreased volume and participation. Finally, in response to the failed oral routine, John said, "Am I talking to myself?" A second subgoal was to introduce chips as a way of demonstrating multiplication, but she had failed to complete the presentation portion that included defining terms. She may have recognized this after mentioning the chips; she said, "Not now. Oh no, no, no, no, no!" The students chorally responded, "Aw, aw." Twain was in some trouble at this point but proceeded.

She pointed to the board and said, "Here is your typical multi — pli — ca — tion pro — blem," and then referred to parts of addition problems and parts of multiplication problems — "The two numbers are called what?" A modest choral response stated "factors," which was written on the board, but when she asked for "product," she lost the students and reprimanded them for not paying attention. Twain then responded to a child who called out. She then directed the students to open their books to page 98. This led into a 10½-min discussion and semipublic practice of problems in the book.

In our theoretical discussion of content presentation (see Figures 2–5), we conceptualized four basic goal states that would govern the actions: definition or terms defined, algorithms presented, algorithms learned, and algorithm understood (through learning and explanation). The presentation of new information is a central part of most math lessons. Presentational objectives consist of a complex system of goals and actions and represent a potential quagmire for the novice. Our two experts started their lesson with an introduction or review of terms. Both experts started with volunteers who were considered weaker and produced failures and moved on to students who were more competent. Subgoal 2A in Figure 4 corresponds to the first goal in Figure 2. The novice did not introduce terms until well into the lesson (Subgoal 1B in Figure 11) and instead used a rather lengthy action string involving conversation routines that seemed to be aimed at arousing interest. In fact, after defining terms midway through the lesson, she omitted most of the presentation and went into the beginning of a selected the numeral and verbal representations (as opposed to pictures, number lines, etc.); neither differentiated very much between new and old material although both had done some of that during the prior conceptual lesson. It is interesting that the novice tried to identify the familiar elements but not in the process of presenting the procedure, and thus the identification was not clear.

The third goal of getting the procedure learned (see Figure 4) was recognized by both experts and to some extent by the novice. The experts called on all the action systems available — board work, choral rehearsal, individual responses, and, in Longbranch's case, statement by the teacher. For both experts, learning is the goal for presenting, and frequent tests of various students are built in to assure that it is achieved. The novice's action of student oral review of problems seems to have been governed more by the goal of getting through the problem than by the goal of learning the material.

Presentation encompasses a large number of routines, actions, and goals. Our description has of necessity been sequential, giving a chronological flavor to the segments. However, actions often occur in more complex patterns, partially satisfying a segment of one goal system or another. Thus, learning actions occur simultaneously or intertwined with presentational ones. The important point is that when presentation is completed, several different goal states have been achieved and the teacher can move to another segment.

Guided Practice

The next major lesson segment was guided practice, which serves as a bridge from the lesson to the students' independent work. The transition from presentation to guided practice was accomplished using four separate subgoals: Children at the board were seated, books were taken out, paper was distributed, and the second group was sent to the board. This was a particularly interesting 1-min segment because it demonstrated the effective calling up of four routines, none involving interactive responses and all of which were simply executed. The teacher's closing statement from the previous activity, "Erase and be seated," initiated the transition. As six children moved back to their seats, the teacher simultaneously said, "Take out your books. Turn to page 169," and passed the paper out to each child in the first row. The books emerged and were opened and paper was passed over heads, one by one, to the last row. There was a brief pause and the teacher said, "Michael's row to the board — first three to the front, second three to the back."

In the first portion of guided practice some children were at the board while others were seated — all were working out problems from the book. There were six cycles of problems. The first subgoal was to work through a problem while keeping both the seated children and the children at the board engaged. The teacher did this by identifying the problem number and having a seated student read it aloud while the students at the board solved it. A second seated child stated the answer and a third explained. This system kept the pace going, involved the whole class, and rehearsed the work.

In the second portion of this segment all of the children were seated while Longbranch called out problem numbers to be done. She went through four sets. The first involved three problems, and each child stood when he or she had completed it. Longbranch gave the answers, then gave five more problems, and went to the desks of the children who were last to stand. She helped them do several problems and then repeated the procedure several more times.

Two experts teaching two lessons on different topics differed, but both used familiar grouping of verbal and physical behaviors to facilitate the smooth running of the class. There was little confusion in cues. What did get confused was quickly cleared up. Without feeling rushed, both experts completed their lessons and provided between 40 and 50 opportunities for rehearsal of the newly learned material.

The differences between novices and experts with respect to lesson structure centered not solely around activity structures, but around routines as well. The novice spent a little more time than the experts in presenting, but not much, and spent considerably more time than the experts in guided practice and less time in monitored practice. However, the novice showed a constantly changing pattern in how she went about these activities. One day, there was a lengthy lecture; the next day, lengthy filling in of a chart of number facts on the blackboard; and the next day, two quizzes sandwiching a presentation. The failure of routines existed in part because there was little or no repetition of them and in part because the novice had not worked them out.

Implications and Importance

Expert teachers constructed their mathematics lessons around a core of activities. This core moved from total teacher control to independent student work. The teachers started with presentations or reviews of information that frequently involved students in some form of focused discussion and moved to public, shared working out of problems; then to very interactive seatwork; and occasionally to independent seatwork. In our observations, teachers used review, drill, tutoring, and testing irregularly but frequently enough that students behaved predictably during them. Occasionally, teachers used an entire lesson to present an especially complex piece of material. They did this by alternating presentations with guided practice.

The presentations and shared presentations of expert teachers were usually quite short. Expert teachers used efficient routines to make effective use of the time spent in guided or monitored practice. For example, Longbranch regularly started by assigning two problems and having the students stand when they finished. This provided her with an easily interpreted perceptual cue as to how students were doing and provided the students with an "action" to engage in upon completion. The teacher used the standing to identify the slowest children and then gave one of those children tutoring during the next round of problems. This routine provided pacing and gave rapid feedback on performance to all of the children. The experts regularly assigned homework but did so only after there had been at least two rehearsals in class, such as guided and monitored practice or textbook plus workbook. With novice teachers, the class was rarely involved in guided practice; instead, the novice often jumped from presentation to practice. Further, the novice teachers often used homework to finish an incomplete lesson. This had two consequences: It made the homework more difficult to do and hence more punishing, and it decreased the chance that it would get done.

The expert teachers had, with the class, a large repertoire of routines, usually with several forms of each one. In some cases, we observed teachers apparently teaching new routines to their classes. The main features of these mutually known routines were that (a) they were very flexible, (b) order could be shifted and pieces taken from one segment and applied to another, (c) little or no monitoring of execution was required, and (d) little or no explanation was required for carrying them out. These routines had simple, transparent objectives: to increase the amount of time that the students were directly engaged in learning or practicing mathematics and receiving feedback, to reduce the cognitive load for the teacher, and to establish a frame that permitted easy transmission of information in mutally known and recognized settings.

In contrast, novices did not work in a routine or habitual way, so each portion of a lesson was different from the next and each day was different. Students, therefore, had to be instructed in their roles and the teachers had to take time and energy to explain each action. Novices spent a little less time than experts presenting material, but the difference was small. Novices spent considerably more time than experts in guided practice and less time in monitored practice. The main difference, though, was that novices displayed a constantly changing pattern in how they performed these activities. A novice might give a lengthy lecture one day, endlessly fill in a chart of number facts on the blackboard the next day, and give two quizzes sandwiching a presentation the third day. A major difference between expert and novice teachers was in the experts' use of well-practiced routines. The absence of routines in the performance of novices was due mainly to their lack of experience, but this was exacerbated by the lack of repetition in the activity structures that the novices used.

The expert's lesson can be characterized as an action agenda consisting of a list of action segments. Each segment has a substantive and unique content, a goal structure, and a consistent knowledge base that is accessed for its completion. Each segment needs certain unique information in order to function. The routines within the segment either produce the information (Who has homework?) or use information recorded from the outcomes of actions occurring in prior segments (Is there a particular type of problem generating difficulty in the homework?). The information schema that retains and makes available information throughout the course of the lesson seems to be arranged very efficiently. The schema lists information with critical properties appended so that information can be assembled in redundant lists for use as needed throughout the lesson and for modification, if necessary, of more stable knowledge, especially about children. Throughout the lesson, the teacher is seeking and using information about the progress of students and the progress of subject matter coverage.

When we consider the massive amount of information that teachers and students must deal with in the course of a single math class, it becomes clear that some techniques must be used to structure the information and limit its complexity. This structuring occurs in part by dividing the 40-min class time into action segments in which the overt behaviors are routinized. The new material can then be plugged into these segments. (This routinization means teachers do not need to take time from instruction to explain how to do boardwork, for example.) A part of the new material is preplanned, whereas another part is a response to the teacher's on-the-spot reading of the way the preplanned segments are going. The use of routines means the teacher has freed herself or himself to focus on the important and/or dynamic features of the material to be transmitted and the information from the students about how the lesson is progressing. Each teacher has three or four variants on each of the approximately 15 routines that are used. The expert teachers retain clearly defined information and are in control of the agenda. New teachers are less able both to obtain and to retain information as well as to maintain control of the agenda. New teachers can benefit from information about different routines, methods of teaching them to students, and ways of using them effectively to maintain student interest. The use of routines reduces the cognitive processing for teachers and provides them with the intellectual and temporal room needed to handle the dynamic portions of the lesson, but we have also seen that experts assemble these actions to achieve goals that, in some cases (presentation, for example), the novice does not seem to recognize as desirable or necessary.

Students also benefit from the presence of goals, action segments, and routines. They can follow instructions and catch up because the sequence of behavior is familiar. They have more time to concentrate on the content of the lesson, or if they prefer, to let their minds wander. The student is relieved of both an interpretation and decision-making element (What am I supposed to do with these six sheets of paper? Which book?).

This type of analysis of routines and activity segments is a useful way of starting to understand how teachers and students deal with a dynamic, ill-structured task setting. Routines and activity segments constrain some of the task elements by making them more or less static and transform some of the tasks into highly standard elements that call up entire repertoires of mutally understood behaviors.

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