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ANALYSING SCIENCE TEACHING FOR NON-ACADEMIC STUDENTS IN SECONDARY SCHOOL

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Analysing Science Teaching for Non-Academic Students in Secondary School," submitted by Margaret E. McCarthy in partial fulfillment of the requirements for the degree Master of Science.

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ABSTRACT

This is a qualitative study of science teaching for non-academic students in secondary school. By "non-academic" students the investigator means those students who are unlikely to pursue a post-secondary programme in the future and who have experienced past difficulty learning the subject (in this case, science). The outcome of the study is a set of seven clues which enable a teacher or observer to identify instances of pedagogical features consistent with Bloom's model of mastery learning and Hirst's concept of teaching, as adapted to non-academic students.

Evidence from earlier studies suggested that few variations in teaching strategies are being used for non-academic students, even though it has been proposed that one way to cater to individual differences in school learning is to alter instructional methods. It is argued that teachers have a responsibility to help these students achieve more academic success and that it is therefore necessary to find effective methods for catering to individual differences in school learning. A review of relevant empirical studies was disappointing, partly due to the fact that the studies were quantitative in nature, concentrating on the frequency of classroom interactions instead of the quality of interactions.

In this study the backbone of the argument is a conceptual connection between learning and teaching: the deceptively simple point that in order to teach something one must appreciate what is required to learn it. The theoretical work is therefore concerned with teaching as it relates to the learning needs of non-academic students. A systematic conceptualization of the teaching which non-academic students need in order to learn is developed. From this conceptualization, the investigator categorizes certain pertinent teaching features which, if emphasized, have the potential to enhance the learning of non-academic students. A set of criteria is then developed empirically for recognizing practical instances of these features. In this way the study establishes epistemological connections between attributes of teaching as determined theoretically (in an "analytic scheme") and their defining characteristics in classroom practice (a "clue structure").

A science unit was taught by the investigator to a class of Grade 10 students and each lesson was audiotaped and transcribed. Selections from this data base were used for analysis and the analysis showed that it is possible to detect instances of an emphasis, or lack of it, on pertinent teaching features.

The possible uses of the clue structure for systematically analysing the quality of teaching in other non-academic classrooms are discussed, with suggestions being presented for further research and practice.

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This thesis is dedicated to

my father

ALFRED EDWARDS

and to my mother

MARY LOUISE EDWARDS

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THE PROBLEM

Focus of the Study

The purpose of this study is to develop a systematic way to detect features of teaching which is consistent with the educational needs of "non-academic" students in secondary school. By "non-academic" students the investigator means those students who are unlikely to pursue a post-secondary programme in the future and who have experienced past difficulty learning the subject (in this case, science). The educational needs of these non-academic students, it will be argued, are different from those of students more academically inclined.

To develop a systematic means to detect features of the teaching, the study is based on a qualitative research technique proposed by Roberts and Russell (1975). This technique involves first producing a theoretically grounded conceptualization of the teaching which non-academic students need in order to learn (this is called an "analytic scheme") and then developing an empirically demonstrated "clue structure" (set of criteria) by which to identify instances of pedagogical strategies consistent with the conceptualization.

A science unit dealing with the topic "Fire" was taught by the investigator to a class of Grade 10 students and each lesson was audio-taped and transcribed. Having experienced some difficulty with science at the Grade 9 level, the students in the class possessed a limited knowledge and understanding of scientific concepts. The teaching occurred over a three week period toward the end of the school year. Eight sequential lessons of sixty-five minutes duration were recorded and transcribed, and selections from this data base constitute the data used for the present study.

It is the investigator's contention that, in general, non-academic students receive a poorer quality of education than do academic students. This is consistent with Goodlad's data (1984). It is often argued that one way to cater to individual differences in school learning is to alter instructional methods. Yet Goodlad's evidence shows that few variations in teaching strategies are to be found: apparently, few attempts are made to enhance the learning of students with differing abilities.

Accepting Goodlad's claim that schools tend to internalize certain myths about school learning, the investigator agrees with him that one should begin with the more optimistic assumption that nearly all children can learn given the appropriate learning conditions. The investigator contends that in order to effectively adapt instruction to suit individual needs one must have a clear conceptualization of teaching as it relates to making provision for school learning. The analytic scheme for the study is based on that conceptualization and the clue structure follows from it.

This document consists of five chapters. The remainder of Chapter One deals with the significance of the problem and the conceptual orientation to be used in the study. Chapter Two presents a review of related literature and this is followed in Chapter Three by the development of a theoretical perspective on teaching as it relates to the learning needs of non-academic students (this is the analytic scheme).

Chapter Four presents the development of a set of criteria (a clue structure) which can be used to detect the presence or absence of an emphasis on certain pedagogical strategies; the development is based on an analysis of three science lessons taught by the investigator. The final chapter includes the investigator's conclusions about the study, its limitations and also its implications for further research and practice.

Significance of the Problem

Based on personal knowledge of science teaching, the investigator estimates that at least fifty per cent of students presently enrolled in science classes in secondary schools will not pursue forms of higher education. That is to say most schools contain large numbers of non-academic students. The problem for this study has to do with the kind of education these students are receiving.

The significance of the problem, for the investigator, is therefore three-fold. (1) There are two distinct "worlds of schooling," as Goodlad calls them. Non-academic students, up to fifty per cent of the school population, inhabit one of these worlds. (2) There is little evidence to suggest that teaching strategies are being modified to meet the needs of non-academic students. (3) The study is an effort to counter the myth that non-academic students are somehow destined to fail in school.

Goodlad: Two Worlds of Schooling

Goodlad (1984), reporting on the results of "A Study of Schooling," an investigation of U.S. schools, found marked differences in the educational opportunities and experiences of different groups of students. Data showed that there is an apparent division of secondary schools, particularly senior high schools, into essentially academic or vocational specialization. In addition, there is a further division of the curriculum and accompanying pedagogy into courses presumed to be devoted to general education but in no way constituting a common core for all.

The data analysed by Goodlad led him to suggest that there are two worlds of schooling, partly overlapping, one preparing for college and the other for jobs. Goodlad expresses the opinion that "tracking" or "streaming" is generally viewed as an organizational device for grouping together students appearing to be reasonably similar in ability and accomplishment. Consequently, researchers have tended not to examine the teaching practices associated with tracking, but have concentrated almost exclusively on the <u>effects</u> of tracking. However, in "A Study of Schooling" the investigators probed into what was going on in the several track levels of the junior and senior high schools studied. The findings from the classes studied revealed significant differences in curricular content, instructional procedures, and elements of the student-teacher relationship.

The curriculum of classes at different track levels varied in the instructional content made available to the students in them. The data obtained on topics taught in junior and senior high schools revealed two distinct types: college preparatory and life, or utilitarian skills. High track classes at both levels could be distinguished from the others by a significantly greater orientation toward college-preparatory topics.

Effective instructional practices were found to be more characteristic of high than low classes. Students in the lower tracks were the least likely to experience the types of instruction most highly associated with achievement. There were distinct differences favouring upper tracks in regard to teachers' clarity, organization, and enthusiasm at both junior and senior high levels. Data also revealed that the environment in the classes at different track levels differed noticeably in the social relationships taking place in them. Students in low track classes saw their teachers as more punitive and less concerned about them than did the other students, while teachers in these classes spent the most class time of any teachers on student behaviour and discipline.

Goodlad believes that these data suggest the probability of marked inequities among students in regard to access to knowledge and sound pedagogical practices. Furthermore, he believes that the implication of these findings may be the most significant and, perhaps, controversial of the entire report. The findings imply that the central problem for today and tomorrow is no longer access to school, but access to knowledge for all. Increasingly, Goodlad suggests, the issue will be whether students, as a consequence of the schools they happen to attend and the classes to which they are assigned, have equality of access to knowledge. At the present, he argues, the assignment of students to the classes regarded as low in a school practising tracking predicts for them diminished access to what increasingly are being recognized as the more satisfactory conditions for learning. The data showed that consistently the practices and atmosphere of the low track classes conveyed lower academic and, indeed, more modest expectations generally, as well as greater teacher reinforcement of behaving, following rules, and conforming.

Alternative Teaching Approaches?

Hirst (1971) presents a conceptualization of teaching that characterizes the activity in such a way as to distinguish it from all other activities. Although Hirst does not suggest that teaching necessarily implies learning, he does emphasize that teaching necessarily implies the intention of bringing about learning by someone. It must therefore be possible for the pupil to learn what it is intended he or she should learn.

> I conclude therefore that a specific teaching activity must necessarily indicatively express the X to be learnt by B and be so related to the present state of B that he can learn X. (p. 15)

It appears from Hirst's conceptualization of teaching that teachers should be adjusting their instructional method when necessary to ensure that it is compatible with the present learning state of the pupils. If so, are such variations in instructional methods evident in the schools today?

Goodlad's data (1984) showed a decline in the modest use of alternative teaching approaches observed in the primary grades with advancement to the higher grades. What emerged was a picture not of different kinds of instructional activities appealing to different types of learners, but of two curricular divisions in secondary schools. Not only did the data show a steady decline in the variety of teaching methods employed but also a decline in the amount of teacher support, feedback, and corrective guidance provided with progression upward through the grades. Goodlad points out that the junior and senior high schools in the sample were characterized by a rather narrow repertoire of instructional procedures and limited attention paid to enhancing the learning of the students.

It is this investigator's contention that in order to effectively adapt instruction to meet individual differences, one must have a clear conceptualization of school learning. If one is aware of factors involved in the learning process, it may be possible to understand why pupils succeed or fail in their learning at school and consequently to assist in the prevention and remediation of learning difficulties.

The Fundamental Myth about Non-academic Students

How is the conceptualization of school learning presently dealt with in schools? Goodlad (1984) asks the question,

> Is the division of secondary schools into students emphasizing vocational studies and others pursuing primarily academic programs a self-fulfilling prophecy reflecting a popular myth about learning that begins its relentless course in the primary grades? (p. 147)

Goodlad believes that schools internalize certain myths about human beings and their ability to learn which are well established in our society. One such myth is the widely held belief that a significant part of the population is destined to have serious difficulties in school, and at best can be prepared only for jobs requiring relatively narrow programmes of preparation. The concept of poor and slow learners, in contrast to good and fast--and the relative irrevocability of those attributes--also is a well established myth not countered in schools, according to Goodlad. He contends that these assumptions and myths are generally accepted by teachers and are at the outset built into classroom organization. Instead of creating circumstances that minimize and compensate for initial disadvantages in learning, teachers unwittingly create conditions that increase the difficulty of eliminating these disadvantages. Practices such as tracking, justified as providing for human individuality, appear instead to result in giving up on many individuals.

Goodlad recommends that schools should begin with the more optimistic pedagogical assumption that nearly all children can learn, given appropriate support, corrective feedback and time. In addition, school principals should set the expectation that it is the teacher's responsibility to have each child succeed. It is Goodlad's opinion that the idea that has great practical significance for the next decade or so is the inherent concept that nearly all students are able to learn mathematics, science, social studies, etcetera if appropriate learning conditions are established.

However, teacher expectations about non-academic students are deeply ingrained. "Expectations" have been defined as "inferences that teachers make about the future academic achievement of students." Consider one such inference, as follows:

A. Equality of instruction for academic and non-academic students leads to inequality of learning outcomes.

A teacher may consider "equality of instruction" as a goal of education, expecting different learning outcomes from academic and non-academic students. According to Goodlad's data it appears that, unfortunately, teachers usually use the same teaching style for teaching non-academic students as they do for academic students, expecting and accepting unequal outcomes. Now consider another inference.

B. Inequality of instruction for academic and non-academic students leads to equality of learning outcomes.

If one takes "equality of learning outcomes" as one's goal, then perhaps "inequality of instruction" may be needed. In any event, a teacher has the choice between the expectations represented by Inference A and those represented by Inference B.

When the teacher _does_ expect equality of learning outcomes, what modifications does he or she make to the methods of instruction provided to the non-academic students? If one agrees that the type of instruction does contribute to the learning outcomes, then a description of these modifications would be of value.

Orientation Of The Study

The investigator has presented the position that teacher expectations about non-academic students are deeply ingrained and are reflected in the quality of instruction provided to these students. It is argued that one cannot study the teaching practices taking place in a "non-academic" classroom (in this case, a science classroom) without taking into account these underlying expectations and the teacher intentions associated with them. To understand the effects of certain teaching strategies requires that one look at both the teacher's actions and the intentions behind them. Teaching is a blend of these two components and the conceptual orientation for the study is based on this fact.

The investigator is of the opinion that the appropriate type of research to use for this study is one that will allow for the consideration of both the technical and intentional components of teaching. For this reason a qualitative research technique will be used because it allows the investigator to study the teaching events within the non-academic science classroom in a holistic rather than a reductionist fashion. In this way the investigator concentrates on the _quality_ of interactions rather than the _frequency_ of interactions.

<u>What "Causes" Events to Happen in a Classroom?</u>

Roberts (1984) points out that if one views teaching as a technical, theoretically determined business one might conceptualize causation from the point of view of theoretical science. This might involve Mill's "method of differences" (for example), in determining what is a cause of classroom events.

> If an instance in which the phenomenon under investigation occurs and an instance in which it does not occur have every circumstance in common save one, that one occurring only in the former, the circumstance in which alone the two instances differ is the effect, or the cause, or an indispensable part of the cause, of the phenomenon. (Mill, 1881/1950, pp. 215-216)

However, Roberts uses the work of Collingwood (1940) to distinguish between the causative links in theoretical natural science ("theoretical causation") and those links in practical affairs ("practical causation"). Roberts believes that in the practice of teaching,

> . . . there are essentially two causative components in practical causation: technical manipulation of conditions antecedent to the event one wishes to influence, and the strength of one's intention or resolve to <u>have</u> the events go that way. (p. 3)

Furthermore, he argues that there is no questioning that teaching is an intentional act and as a result any conceptualization of what "causes" classroom events must consider the determination with which the teacher pursues his or her intentions. The strength of a teacher's intention to carry out a certain action is just as important a causative influence, Roberts contends, as the technical elements of teaching style, curriculum materials, etcetera. Neither is necessarily more important than the other, but neither is sufficient by itself in conceptualizing the "cause" of events in a classroom.

For purposes of the present study, the significance of the distinction between theoretical and practical causation is bound up in the importance of teacher expectations, discussed above. It is vital to be able to comment upon the reasons for teacher actions and these derive from the teacher's intentions.

A Comparison of Quantitative and Qualitative Research

Kilbourn (1980), in discussing quantitative research carried out in science classrooms, argues that this type of research is based on "the scientific research paradigm," wherein the knowledge obtained as a result of classroom observation is objective. Thus, researchers claim that this knowledge about classroom events can be replicated by any competent researcher using the same observational perspective. The aim is to produce sound scientific generalizations about classroom phenomena. However, as Kilbourn points out,

> One ramification of this is that by focussing on those aspects of the classroom that are generalizable (rather than on the unique and particular) the intentions and motives of both teachers and students are ignored. Intentions and motives are part of the matrix of "contextual particulars" which contribute to the reality of any given classroom. As Power notes, these particulars are discounted in favor of producing stable generalizations.
> (Kilbourn, 1980, p. 165)

Kilbourn contrasts quantitative research with qualitative or ethnographic research. In the latter there is no intent to generalize classroom descriptions to entire populations; rather the attempt is to provide holistic descriptions of particular classrooms. Kilbourn discusses the fact that qualitative research is based on "the ethnographic research paradigm," wherein it is important to recognize the context in which events take place in a classroom. Consequently, a conscious effort is made to preserve and take into account contextual features such as intentions and motivations of teachers and students. Kilbourn contends that these and other contextual aspects are not seen as contaminating variables to be controlled (as in the scientific paradigm) but instead are considered to be essential for a thorough understanding of the events observed. The assumption is that significant descriptions of the classroom must take into account the intentions of the participants and how they view what is happening.

Summary

This investigator's concern is with the quality of instruction being provided to the large number of non-academic students in our secondary schools today, specifically those enrolled in science courses. Goodlad (1984) noted that researchers have tended not to examine the teaching practices associated with tracking. At the same time his data suggested that non-academic students have diminished access to the more satisfactory conditions of learning. The investigator rejects the widely held opinion that non-academic students are destined to fail in school, believing instead that these students can succeed academically if presented with teaching strategies that are consistent with their educational needs.

In this study the investigator is the teacher, and there is evidence that students experience success. The teaching incorporates certain pedagogical features which a research methodology must detect systematically, if the purpose of the research is to be fulfilled.

In an attempt to detect the presence or absence of certain pedagogical features that might enhance the learning of these students, the investigator contends that in order to conceptualize what "causes" events to happen (in this instance, what causes students to learn better) one must consider both the technical and intentional components of teaching. This is consistent with Roberts' (1984) work on "practical causation."

The investigator believes that a holistic or contextualist study of the phenomenon will allow for this complete conceptualization of the quality of classroom interaction. This belief is strengthened by Kilbourn's (1980) comparison of qualitative and quantitative science education research. As will be described in greater detail in Chapter Two, the review of related literature shows that previous studies have taken a reductionistic approach, looking at the frequency of interactions rather than at the quality of interactions. For these reasons the investigator has chosen to use a qualitative research technique, one proposed by Roberts and Russell (1975). Only such a qualitative technique will allow for the description of both technical and intentional aspects of teaching that is necessary for an adequate, systematic description of the events being studied.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter presents a review of three distinct groups of studies: (1) "Mastery Learning" studies, (2) "Aptitude-Treatment Interaction" studies, and (3) "Classroom Management" studies. The investigator explains why these studies are considered to be the most relevant before presenting the detailed description of the studies and their findings. A summary of the findings is provided for each group and the relationship of the literature to the study is discussed in the final section of the chapter.

Selection of Appropriate Studies

We have in existence in our secondary schools today, classes of non-academic students who are receiving, in general, a poorer quality of instruction than students more academically oriented. The investigator contends that teachers have a responsibility to help these students achieve more academic success and that it is therefore necessary to find effective methods for catering to individual differences in school learning. Thus it was decided to review studies of any such methodologies.

Over the years, administrative arrangements such as "streaming," altering the duration of schooling, or altering the duration of instruction have been used in an attempt to meet individual learning needs. In addition, alterations in instructional techniques have been attempted and these techniques fall into two categories. (1) Remedial help is offered to supplement regular classroom instruction. This forms the basis of mastery learning strategies. (2) Different pupils are taught by different methods. Aptitude-treatment interaction methods use this approach to cater to individual learning needs.

The investigator believes that the more promising approach is to alter the method of instruction, because variations in teaching strategies can produce some dramatic results. Torrance (1965) expressed this same opinion when he wrote:

> I suppose alert teachers have always been intuitively aware of the fact that when they change their method of teaching that certain children who had appeared to be slow learners or even non-learners became outstanding achievers and some of their former star learners became slow learners. (p. 253)

Hence it was thought that a review of "mastery learning" studies and "aptitude-treatment interaction" studies would provide an insight into the effectiveness of these two techniques with respect to improving academic achievement. The two techniques are described briefly, below.

Bloom based his "mastery instructional strategy" on the model of school learning proposed by John Carroll (1963). Of the variables outlined by Carroll, the teacher was able to control "opportunity to learn" and the "quality of instruction," so Bloom (1976) outlined methods that would enable the so called slow learners to obtain the extra time and help they needed. Bloom chose to concentrate his attention on the "feedback-correctives" element of instruction. He worked with "heterogeneous ability" groups of students, providing them all with the same group instruction but attempting to erase individual differences in learning by providing additional extra help in the form of a diagnosis-remediation system.

In contrast, "aptitude-treatment interaction" studies have examined the possibility of identifying student "typologies." Then, instructional modes that best suit the learning needs of these students are identified.

Because the investigator's interest is in the quality of interactions occurring in non-academic science classrooms, it seemed important to determine if previous studies had already documented the educational events taking place within such classrooms. The specific concern was how the teacher handled, or managed, the learning process. For these reasons, "classroom management" studies were also chosen for inclusion in the literature review. A literature search of "teaching styles," "teacher characteristics," "classroom environment," and "classroom interaction" produced no information relevant to this study.

Mastery Learning Studies

The literature search revealed that Bloom's mastery learning model has been modified in many ways during implementation in secondary science classrooms. These modifications of the model have been restricted almost totally to the "diagnosis-remediation" part of the model.

No Modification to the Model

Three of the studies used strategies essentially the same as those used by Bloom, making little or no attempt at modification.

Strasler and Others (1981) presented an evaluation of competency-based school programmes in a "learning for mastery" setting. Evaluation utilizing comparison group designs was conducted and used to compare the performance of students receiving corrective instruction with an equivalent control group that did not. Results of analysis of data from locally developed summative tests revealed positive trends in the attainment of competencies in grades 6 and 8 science.

Dunkelberger and Knight (1981) carried out research to determine if grade nine students experiencing similar instructional characteristics but participating in either mastery or traditional labs would demonstrate significantly different concept retention. Subjects were academically oriented students who on the average scored slightly above the fiftieth percentile on the ability tests administered statewide to all eighth grade students at the end of the previous year. The experimental treatment consisted of mastery based laboratory instruction that included (1) behavioural objectives, (2) self-paced laboratory experiments and activities, (3) self checking quizzes, and (4) criterion-referenced test items. Students worked at their own rates to complete various laboratory activities and the associated library research. Upon completion of the material, students were given a mimeographed quiz consisting of eight to twelve items, each keyed to a specific objective. The test results were used to direct students to new laboratory activities, or if necessary, to remedial work and a subsequent retest, if the student received less than the 70% criterion score. The data strongly supported the premise that students receiving mastery based instruction demonstrated greater achievement. The authors acknowledge, however, that this finding is of a tentative nature since the reliability of the assessment instrument was marginal and the validation of items limited.

Wortham (1980) reported on a project designed to determine whether mastery learning instruction at the secondary level is more effective than other instructional strategies. Seven teams of teachers in five school districts participated in the investigation. The resources developed and used by the teachers included the development of unit sequences, the development of unit tables of specifications, the writing of formative and summative tests, and planning of corrective teaching activities. At the end of the project, although not all of the teachers completely endorsed mastery learning as a means to improve student achievement, they did agree that the training, and teaching on the basis of mastery learning, had improved their planning and instruction by infusing specificity into it.

Diagnostic Testing with Modified Remediation

The following three studies involve modifications in the diagnosis-remediation portion of the mastery learning model. It appears that most of the modifications are, to a certain extent, an attempt to make the implementation of mastery learning strategies more feasible, by reducing the amount of time involved.

Burkman and Brezin (1981) examined the effects of a modified mastery learning system on achievement in an individualized high school physical science course. The study was designed to determine if the improved achievement advantage of mastery teaching could be accomplished without consuming an inordinate amount of time. The modification made was to set performance (mastery) standards but to limit time available for study and remediation. Students who were unable to achieve the performance standard in the time available were moved on to the next learning task. In addition, the standards set for mastery were altered from a high expectation level to a medium level and then a low expectation level. The initial subjects for the study were 1,089 students enrolled in the first segment of a physical science course. The students were in 32 classes taught by 12 teachers. Distribution across grade levels was as follows: 9th grade, 64%; 10th grade, 24%; 11th grade, 7%; and 12th grade, 5%. The results indicated that medium mastery standards were superior to both high and low standards for promoting achievement in both difficult and easily learned materials. The authors suggested that it appeared that both time available for study and performance standard level can be set too high or too low for optimal effect.

Lueckemeyer and Chiapetta (1981) investigated the effects of a modified mastery strategy on achievement in a high school human physiology unit. Their modification of Bloom's mastery format was to make the remediation period limited and prescriptive, rather than unlimited, in order to accommodate the time limitations of the classroom. The subjects of the study were 185 tenth grade students enrolled in 12 introductory biology classes in a suburban high school. Their results showed that this modified mastery learning format resulted in only a small degree of improvement in the achievement of students on high school physiology subject matter. In addition, this type of instruction was not effective in producing a reduction of variance in achievement nor in retention of subject matter knowledge. The authors therefore concluded that somewhere in between the limited remediation procedure used in their study and the unlimited remediation procedure recommended by Bloom might exist a practical and effective approach for the public school classroom.

Swanson and Denton (1976) carried out a study comparing remediation systems in mastery learning and the effects on achievement and retention in chemistry. The investigation involved a chemistry learning sequence with 53 eleventh and twelfth grade students, and tests were administered to measure both progress during the sequence and achievement and retention after the sequence. One of three types of remedial work was prescribed for those achieving less than mastery. Group one received treatment modelled after Bloom's mastery system (small group study, peer tutoring, self study, discussions with the teacher). Group two received the Personalized System of Instruction remediation (repeating reading and problem assignments, review notes, and laboratory reports). Group three received no further instruction on the objectives but was given optional assignments to improve grade level. The data revealed (1) that remediation positively influences cognitive achievement and retention, and (2) the use of alternate materials and activities under teacher direction provides more optimum learning conditions than repeating the learning activities and reviewing the reading materials previously encountered.

Diagnostic Testing Without Remediation

Dunkelberger and Heikkinen (1984) investigated the influence on learner outcomes of the repeatable testing provision of Bloom's mastery learning model for ninth graders in an Introduction to Chemistry and Physics course. The subjects were 273 students who were typically upper middle class suburban youths who scored slightly above average on state-administered verbal aptitude tests. The experiment followed a pre-test/post-test control group design and the two groups differed only in the availability of re-testing and in the demonstration of criterion-level achievement which that procedure required. Student-directed remediation was available to both groups. Contrary to theoretical expectations, neither student achievement nor student attitude toward learning science was favorably influenced by the presence of the repeatable testing component. Further, such provisions failed to significantly lower the achievement-aptitude correlation. The authors conclude that perhaps cognitive gains obtained within mastery learning are attributable to remediation itself, rather than to the re-testing and demonstration of achievement at a criterion level. Furthermore, they argue that since repeatable testing contributes substantially to the logistic difficulties of implementing mastery learning in the classroom, the appeal of the learning model could be enhanced if the implications of this study are upheld.

Brown and Butts (1979) explored the instructional effectiveness of diagnostic testing in mastery teaching. A set of objectives with diagnostic tests were taught to high school students in one of two human physiology classes; the other class was taught by standard instructional methods. The participants in the study were sixty high school students ranging from sixteen to eighteen years of age, part of a generally middle socioeconomic level population attending a comprehensive public high school. In addition to the standard instruction, the treatment group was given diagnostic tests and instructions for using test results to help their learning. No evidence to support the influence of diagnostic testing on student achievement was found. The authors concluded that it appears that this one method alone, without teacher-directed remediation and the rest of the mastery teaching strategy, is apparently not enough to increase teaching effectiveness.

Reduced Cycles of Diagnosis-remediation

Dillashaw and Okey (1983) studied the effects of a modified mastery learning strategy on achievement, attitudes, and on-task behaviour of high school chemistry students. They expressed the opinion that the use of mastery learning may be viewed as more feasible by teachers if significant achievement gains can be made with a fixed number of diagnosis-remediation loops and if students can be given the responsibility for directing remediation. Consequently, in the study, diagnosis-remediation was limited to two cycles and three treatment groups were used: Treatment 1 - no diagnostic quizzes or remediation activities, Treatment 2 - student-directed remediation, Treatment 3 - teacher directed remediation. The experimental sample consisted of 156 students from nine classes enrolled in first-year chemistry in an urban-suburban high school. The classes were relatively heterogeneous with respect to grade level, race, and aptitude. The results showed that both variations of the mastery learning strategy produced an increase in on-task behaviour and an increase in achievement. However, the results did not support the hypothesis that the mastery learning strategy could result in more positive attitudes paralleling higher achievement gains. Neither did the study support Bloom's hypothesis that a mastery learning strategy can decrease differences in achievement among aptitude levels. The authors suggest that this is possibly because the modification to two cycles of diagnosis and remediation may not be sufficient to reduce the differences in achievement among aptitude groups.

Most "Radical" Modification

The most "radical" modification of Bloom's model that the investigator came across in the literature search was in a project reported by Fleming and Others (1983). The authors have developed a programme called Choice Chemistry, which is a multi-level course written in a style for use in Scotland, but adaptable for other areas. The mastery approach has been modified by devising a branching pattern of the "core and extension" type. Every pupil is expected to master the core part of each topic and then go on to experience achievement in one of the extensions at a level suited to their ability. In this way the authors hope to avoid academic hurdles that would be too difficult to cope with (at least in a reasonable span of time) for the bulk of the population.

Summary

The review of mastery learning studies carried out in secondary science classes showed that various conclusions have been reached as to the effectiveness of this type of instruction. Only one study of unmodified mastery learning instruction claimed definite positive trends in achievement, while another two tentatively endorsed mastery learning as a means to improve achievement. The review also revealed that when the technique of mastery learning instruction is modified by altering the diagnosis-remediation cycles, then improvement in student achievement is not always accomplished. The studies conducted by Lueckemeyer and Chiapetta (1981), Dillashaw and Okey (1983), and Dunkelberger and Heikkinen (1984), which produced no decrease in differences in achievement among aptitude levels, suggest that the problem of trying to meet individual learning needs still requires further investigation.

Aptitude-Treatment Interaction Studies

Are Outcomes Affected by Aptitude and Treatment?

A study by Power (1973) explored a multivariate model for predicting instructional outcomes based on the assumption that the latter are determined by the total pattern of interactions between the person and his learning environment. The findings support the claim made by Goodlad (1984) that the same environment is in fact different for different students with regard to teacher-student interactions.

According to Power, outcomes were found to be related to communication patterns and pupil characteristics in four independent ways, and he suggested that these relationships represent "syndromes" which seem to represent a fairly predictable sequence of events. He believes that combinations of personal traits and teacher attention lead to: (a) success in all aspects of the classroom game, (b) academic but not social success, (c) social but not academic success and to negative attitudes towards science, (d) academic and social failure.

Three Studies Reviewed

Good and Power (1976) used the data collected by Power in 1973 (as outlined above) in an attempt to design successful classroom environments for different types of students. They contend that the same environment has different effects on different students and also that different environments have different effects on the same student. Using the four typologies of students developed by Power (1973)--success, rejection-dependency, person-oriented, and social-alienation--Good and Power suggest a treatment model, attempting to identify classroom variables that they believe are among the critical forces that shape student classroom progress. They distinguish between five modes of instruction (group with teacher, group without teacher, large group with teacher, individual with teacher, individual without teacher) and recommend certain amounts of instructional time in the different instructional modes for each type of student. It is their belief that teachers who are willing to vary their instructional setting can probably achieve a better balance, and more achievement, than teachers with similar instructional capabilities who utilise but one learning model.

Koran and Koran (1984) discuss aptitude-treatment interaction research in science education. The article identifies promising areas of ATI research as well as general methodological guidelines for interested science educators. The authors concentrate on four individual difference variables that they believe consistently correlate with learning and also tend to give relatively consistent ATI results. These four variables are general ability, anxiety, prior achievement, and achievement orientation.

Having reviewed the literature concerning general ability, Koran and Koran present the general hypothesis that instructional treatments differ in the information processing burdens they place on, or remove from, the responsibility of the learner. They argue that studies have shown that as instructional treatments are arranged to relieve learners from difficult reading, analysing complex concepts, and building their own cognitive structures, the more such treatments seem to compensate for or circumvent less able learners' weaknesses. In other words, the more of the required information processing that the instruction performs for the learner, the better that instruction is for low ability learners. Conversely, the more of the required information processing which is left to the learner, the better that instruction is for high ability learners.

The authors summarize studies that have been done to establish the existence of aptitude-treatment interactions when general ability is considered to be the aptitude variable. They cite the use of programmed instruction as the treatment (Cowen, 1967; Owen, Hall, Anderson & Smart, 1965; Pyatte, 1969); the use of advance organizers (Koran & Koran, 1973; Ausubel & Fitzgerald, 1962); a comparison of inductive methods and deductive methods (Koran, 1971; Koran & Koran, 1979). They point out that it appears that highly verbal and abstract conceptual treatments are particularly good for high ability students, while simple diagrams, figures and symbolic constructions can be used to replace or supplement abstract interpretations to benefit low ability students (Koran & Koran, 1981; Winn, 1980, 1981; Holliday, Brunner & Donais, 1977).

The authors then summarize studies in which prior learning experiences, or achievement of the learner, is taken as the aptitude variable. The study by Tobias (1976) led to the statement of a general hypothesis predicting an inverse relationship between prior knowledge and amount of instructional support required to attain instructional objectives. This hypothesis implies that the lower the level of prior achievement, the more assistance needs to be provided to the learner in order to attain the instructional objectives. On the other hand, the higher the level of prior achievement, the less such assistance is needed by students.

Koran and Koran cite several studies to support this achievement-treatment hypothesis. The study by Ott (1976) compared mastery based instruction versus regular class instruction in the teaching of physics;

Dyer & Kulhavey (1974) compared well organized versus randomly organized content in teaching biological information; Deboer (1981) studied the effects of retesting on chemistry achievement. However, the authors also point out that the study of Tobias & Redfield (1980) produced findings that failed to support the achievement-treatment hypothesis.

Lehman, Koran & Koran (1984) carried out a study of the interaction of learner characteristics with learning from three models of the periodic table. The study was designed to explore the effects on learning of: (1) structural modifications to the periodic table, (2) the location of a periodic table within instructional materials, and (3) the presence of a two page schema showing relationships between the topics explained in the written materials and the periodic table. The results showed that students high in verbal comprehension tended to take advantage of the modified tables, while those low in verbal comprehension processed the traditional table with less information most effectively. These latter students also benefited more from having the periodic table alongside their written materials.

Summary

It appeared from the literature review that many attempts have been made in science education to cater to individual learning needs by identifying specific aptitude-treatment interactions. However, the review also revealed that in the ATI studies the composition of groups is usually based upon a few characteristics and the treatment based upon only a few classroom variables. This is a disadvantage in that the reductionist definitions of treatment groups and treatments may not adequately represent students and their needs. In addition, theoretical decisions like this may undercut the teacher's determination to succeed.

As Good and Power (1976) point out, it is unlikely that a single dimension is sufficient to represent adequately the learning needs of a student. They therefore feel that definitions of treatment groups and treatment need to become more complex than those typically used in ATI studies, recommending the use of several "anchor points" to adequately represent students and their needs.

Science Classroom Management Studies

Four Studies Reviewed

Beasley (1983) believes that the actions of science teachers which maximize the attention of students to the allocated task need to be identified and described. His article describes the management behaviour of junior high school science teachers and the relationship to the task involvement of students operating in small group laboratory settings. The results suggest that teachers who operate more at the whole class level have classes with a higher degree of task involvement. Beasley contends that this teacher behaviour is consistent with those actions of teachers who believe small group laboratory activities are best managed by a constant teacher presence at the whole class level. He concludes that teacher involvement at the whole class level is appropriate if pupil task involvement is an acceptable criterion of management effectiveness.

McGarity and Butts (1984) designed a study to determine the relationships between teacher classroom management behaviour, student engagement, and student achievement of middle and high school science students. These variables were investigated across varying levels of academic aptitude. Twelve selected management indicators were used to measure teacher classroom management behaviours and the particular management behaviours which were correlated with achievement and engagement were: identifies students who do not understand directions and helps them individually, maintains learner involvement in lessons, reinforces and encourages the efforts of learners to maintain involvement, attends to routine tasks, uses instructional time efficiently, provides feedback to learners about their behaviour, manages disruptive behaviour among learners.

The study reported four findings. (1) Teacher management behaviour is related to both student engagement and student science achievement. (2) Student engagement is related to student science achievement. (3) Scholastic aptitude is related to engagement: high aptitude students spend more time engaged than low aptitude students. (4) Students of all aptitude levels spend more time engaged when taught by teachers who exhibited competency in classroom management. The authors conclude that science teachers should strive to present materials that will be interesting enough to promote engagement and to exhibit behaviours that will keep students on task such as moving among learners, frowning at misbehaviour, and other nonverbal behaviour. They argue that a classroom that is well managed and provides an atmosphere conducive to learning makes it easier for the student to pay attention.

Tobin (1984) carried out a study to investigate the relationships between teaching behaviours and student engagement in 13 middle school science classes. The results indicated that seven managerial variables and four instructional variables were significantly related to student engagement rates. The effects produced by the four instructional variables were these. (1) Student engagement rates tended to be higher in classes where materials and equipment were used to provide students with opportunities to practise and achieve the objectives. (2) Teachers also used aids to augment explanations, demonstrations, and discussions. The results indicated that student engagement rates were higher when the aids used blended smoothly with other kinds of instruction. (3) High rates of student engagement also tended to be associated with classes where various teaching methods were used. Students tend to remain on task if they actively engage in a variety of different ways during a lesson. (4) A fourth significant relationship with engagement occurred in classes where assessment procedures were used to determine whether individual students received sufficient practice on the objectives. The assessments were typically carried out by teacher questioning, and feedback was provided on correct and incorrect responses.

Sanford (1984) used sub-samples of more and less effective managers and analysed narrative data from their classes in order to describe and illustrate effective strategies for managing science classroom activities. Measures of student on-task, off-task, and disruptive behaviour were used as criteria for management effectiveness. Correlation of classroom management and instructional organizational variables with student behaviour criteria identified a large number of teacher practices significantly related to high levels of task engagement and freedom from disruption in science classes. The instructional variables dealt with organizing and pacing instructional activities and presenting information. Based on consistent significant correlations, the most important variables in this area were: describing objectives clearly, clear directions, waiting for students' attention before giving directions, appropriate pacing of lessons, clear explanations and presentations, planning appropriate amount of work for the class period, and efficient transitions. Sanford contends that significant correlations for three additional variables underscore the importance of pacing and accommodating student abilities and characteristics. These variables are: (1) student success rate (a global rating of apparent class frustration levels or ability to comply with assignment directions), (2) student attention spans considered in the lesson, (3) monitoring student understanding.

Summary

This literature review of classroom management studies carried out in secondary science classrooms revealed that researchers have tried to identify teacher management strategies that maximize student participation in lessons. Managerial variables, related to control of the learners, and instructional variables, related to control of the learning, have both produced significant correlations with student participation. However, in several studies little attempt was made to differentiate between managerial and instructional variables and the investigator could find no evidence of an attempt being made to study only instructional variables. From the literature search, it seems that the emphasis is on the study of "management of learners" to encourage participation rather than studying "management of learning" to increase instructional effectiveness.

Relationship of the Literature to the Study

The investigator believed that a review of methodologies designed to cater to individual differences in school learning, and a review of studies documenting educational events within science classrooms, would be most relevant. These studies were reviewed, reported upon and several points were noted. The review of mastery learning studies showed that improvement in student achievement is not always accomplished, particularly when the technique of mastery learning instruction is modified. Although many attempts have been made to identify specific aptitude-treatment interactions, the review revealed that the composition of groups is usually based upon a few characteristics and the treatment based upon only a few classroom variables. Classroom management studies revealed that little attempt was made to differentiate between managerial variables, related to control of the learner, and instructional variables, related to control of the learning.

From the literature review it appears that researchers are: (1) concentrating on the management of the learners instead of the learning, (2) looking at classroom events in terms of the effects, but not the causes, and (3) studying variables over which the teacher has little control, in many cases, instead of studying the teaching itself. These points confirmed the investigator's resolve to proceed in the present study by concentrating on <u>conceptualizing the teaching</u> in non-academic science classrooms, using a methodology quite different from that of the studies reviewed.

Chapter 3

THEORETICAL FRAMEWORK AND ANALYTIC SCHEME

The purpose of this chapter is to develop and present a systematic conceptualization of the teaching which non-academic students need in order to learn. The reader will recall that the methodology the investigator is using is aimed at finding ways to detect the presence or absence of certain features of teaching in a non-academic science classroom. Developing a systematic conceptualization of the features being looked for--that is, an analytic scheme--is the first step, and that is the concern of the present chapter. The clue structure that makes possible the detection of appropriate teaching strategies is derived from the analytic scheme and is then empirically demonstrated and refined through data analysis in Chapter Four.

With respect to conceptualizing the teaching which non-academic students need in order to learn, the investigator's approach will be first to consider a classic treatment of the concept of teaching (Hirst, 1971), which clearly reveals the conceptual connection between teaching and learning. However, it must be noted that Hirst deals with teaching in general and, to repeat the argument presented in Chapter One, it is contended that teaching strategies used with more academic students need to be modified if they are to become effective for non-academic students. If these modifications are not made, the result is inequality of learning outcomes, but the argument is that it is possible to improve non-academic students' achievement if they are presented with favourable learning conditions. This is consistent with Bloom's work (1976, 1981).

The investigator's task thus becomes one of conceptualizing the modifications needed in order for teaching strategies to be consistent with the learning needs of non-academic students. The features of teaching mentioned by Hirst are the same for both academic and non-academic students but it is argued that these features need to be exaggerated for non-academic students. Use is therefore made of Bloom's (1976) definition of "cues" to provide an insight into how such exaggerations might be made, while Carroll's work (1963) regarding "quality of instruction" and "ability to understand instruction" provides clarification of what features of teaching might be emphasized. In the remainder of the chapter these works will be dealt with in more detail.

Conceptualizing the Teaching Which Non-academic Students Need

Bloom (1976) points out that the existence of individual differences in school learning is unquestioned. Furthermore, he acknowledges that there is considerable evidence that differences which appear relatively early (by Grade Three) in school achievement tend to remain and even increase over the many years of school. He cites longitudinal research studies that make it clear that the differences in measured achievement found between students at one grade level do not disappear at a later grade level.

In spite of all the evidence on the existence and stability of differences in school learning, Bloom (1976) has asserted that

> . . . much of individual differences in school learning may be regarded as man-made and accidental rather than as fixed in the individual at the time of conception. (p. 9)

In order to account for the apparent stability of these differences in school learning, Bloom (1981) refers to the model proposed by Carroll

(1963) and states the following hypothesis. If the students are normally distributed with respect to aptitude for some subject and all the students are provided with exactly the same instruction (same in terms of amount of instruction, quality of instruction, and time available for learning), the end result will be a normal distribution on an appropriate measure of achievement. However, Bloom stresses that,

> . . . most students become very similar with regard to learning ability, rate of learning, and motivation for further learning when provided with favorable learning conditions. (p. 135)

For purposes of the present study, "favourable learning conditions" is the key phrase. It was known at the beginning of the study that the non-academic science students featured here are the students who constitute the low end of the distribution on achievement measures--at least, that has been their history in science classes. Accordingly, what is needed is a systematic means for characterizing the type of teaching that "works" for them, i.e., that accommodates their learning characteristics. This teaching incorporates features which are exaggerated, or stressed, in ways which are not so critical to the learning of academically inclined students. In order to bring out the exaggeration of these features, the investigator has first considered a lucid treatment of what it means to teach <u>at all</u>--namely, Paul Hirst's classic treatment of the question, "What is teaching?".

<u>A General Analysis of Teaching and Learning: Hirst</u>

Paul Hirst (1971) provided a conceptualization of "teaching" in an attempt to ". . . characterize the activity of teaching so as to distinguish it from all other activities" (p. 6). He felt that such a conceptualization is necessary for several reasons. One reason is that the way in which teachers understand teaching very much affects what they actually do in the classroom. Hirst believes that it is very important for a teacher to be clear about the nature of the central activity in which he or she is professionally involved. In addition, Hirst stresses the need for carefully controlled empirical research on the effectiveness of different teaching methods, but he points out that without the clearest concept of what teaching is, it is impossible to find appropriate behavioural criteria with which to assess classroom events.

Hirst contends that the intention of all teaching activities is to bring about learning and that this statement has important implications.

> It involves the claim that the concept of teaching is in fact totally unintelligible without a grasp of the concept of learning. It asserts that there is no such thing as teaching without the intention to bring about learning and that therefore one cannot characterize teaching independently of characterizing learning. Until therefore we know what learning is, it is impossible for us to know what teaching is. The one concept is totally dependent on the other. Because of the tightest conceptual connection then, the characterization and raison d'etre of teaching rests on that of learning. (Hirst, 1971, p. 9)

Consequently, in order to clarify the characterization of teaching, Hirst proceeds to define what is meant by "learning." Again he believes that a promising approach is to look at the intention of the activities involved in learning. The end or aim of learning is always to produce some specific achievement or end state and because there is a variety of these achievements or end states with which learning is concerned, then it is not surprising that the activities of learning are equally varied.

When Hirst combines this characterization of learning with his previous statements concerning the intentional aspect of teaching activities, he summarizes his account of teaching in the following way:

> A teaching activity is the activity of a person, A (the teacher), the intention of which is to bring about an activity (learning) by a

> person, B (the pupil), the intention of which is to achieve some end-state (e.g. knowing, appreciating) whose object is X (e.g. a belief, attitude, skill). (p. 12)

This is simplified and expressed in the following way:

> Teaching is the label for those activities of a person A, the intention of which is to bring about in another person B, the intentional learning of X. (p. 13)

However, Hirst cautions that there are some necessary conditions which an activity must satisfy before it can possibly be described as a teaching activity. He specifies two necessary features of a publicly observable kind which all teaching activities must possess. First, the activity must, either implicitly or explicitly, express the X to be learned, so that this X is clearly indicated to the pupil as what he or she is to learn. In this way, Hirst contends, the teacher makes plain in his activity what he intends to be learned. Second, the teaching activity must take place at a level where the pupil can understand what it is intended he or she should learn. In other words, it must be possible for learning to take place. Hirst summarizes these features in the following way:

> I conclude therefore that a specific teaching activity must necessarily indicatively express the X to be learnt by B and be so related to the present state of B that he can learn X. (p. 15)

Although Hirst is not suggesting that teaching necessarily implies learning, he does emphasize that teaching does necessarily imply the intention of bringing about learning by someone, and that if from one's activities it is impossible for someone to learn what is intended, it would be odd to describe such activities as teaching.

According to Hirst, traditional teaching methods have concerned themselves with the indicative features of these activities, often meeting the present learning state of the pupils in an over-generalized and inadequate way. However, it is his contention that in all teaching activities both of these necessary features need the fullest responsible consideration.

Hirst has used his conceptualization of teaching to demonstrate how one can analyse the steps involved in a teaching activity. He points out that one must start at the other end of a logical chain of relations, with an understanding of the end achievements to which everything is being directed.

> From this one can proceed to understand what is involved in B's achieving such ends, in learning X, and then proceed to an understanding of what is involved in A teaching B, X. This logical dependence of teaching on learning, and learning on the nature of the achievements to which it is directed is thus once more no mere academic matter. If teachers are not clear what end achievements their teaching is concerned with, they cannot know what is involved in B's learning X. And until they know what is involved in B's learning X, they cannot know what is involved in A's teaching B, X. (pp. 12-13)

Hirst's characterization of teaching has clearly related the concept of teaching to the concept of learning and has also presented a system whereby one can analyse teaching. This system stresses the dependence of teaching on learning, emphasizing the fact that in order to teach a specific "task" one must appreciate what is required to learn that task. Hirst's work has characterized teaching in general but has not addressed the specific problem of teaching non-academic students, which is the concern of the present study. It has, however, identified the necessary conditions which an activity must satisfy in order to be called a teaching activity.

Considering the first feature, namely that the teacher makes plain in his or her activity <u>what</u> he or she intends to be learned, the investigator pursues the argument that this feature needs to be exaggerated for non-academic students if one hopes for improved achievement. It is the investigator's experience that these students do not easily comprehend the purpose of the work being carried out in the classroom, so if the teacher does not emphasize this purpose the students become involved in details of what they are doing, with little understanding of what is to be learned from it. In order to provide an insight into how such an emphasis might be made, the investigator has examined Bloom's work (1976) regarding the use of "cues."

Indicating to Non-academic Students What is to be Learned: Bloom

Bloom (1976) identifies four component elements of "quality of instruction": the cues or directions provided to the learner, the participation of the learner (overt and covert) in the learning activity, the reinforcement which the learner secures in some relation to the learning, and a feedback and corrective system. According to Bloom the cues include instruction as to what is to be learned as well as the directions as to what the learner is to do in the learning process. He believes that cues can be presented in many forms and that one should be aware that cues differ not only in the form in which they are presented but also in their strength. A cue may become stronger by repetition and by other arrangements which bring it to the attention of the learner, thereby getting the learner to focus on the cues to be learned as opposed to the many other competing aspects of the particular environment.

Bloom points out that another aspect of cues has to do with their meaningfulness, because the cues must be understood or comprehended if the student is to make use of them in the learning process. Related to this must be an awareness on the part of the teacher that learners may differ in the extent to which they can learn from particular cues. Bloom therefore advocates that a variety of instructional materials and methods be used within a classroom to increase the likelihood that each student will secure the cues he needs for his learning. He argues (Bloom, 1981) that:

> It seems reasonable to expect that some students will need more concrete illustrations and explanations than will others; some students may need more examples to get an idea than do others; some students may need more approval and reinforcement than others; and some students may even need to have several repetitions of the explanation while others may be able to get it the first time. (p. 159)

With respect to this study, Bloom's work is of value because it highlights the fact that students do differ in their ability to understand what is to be learned. It also supports the investigator's opinion that the teacher must find ways to emphasize the directions provided to some students. Finally, Bloom's work provides insights into how this emphasis might be accomplished.

Hirst stated that a second necessary condition of a teaching activity is that it must take place at an appropriate level so that the student can understand what it is intended he or she should learn. The investigator again draws upon personal experience to comment that non-academic students often have difficulty understanding the reasoning being used by the teacher as information is presented to them. As a result, they often interpret this information in an inappropriate context and this limits their comprehension and subsequent learning. Carroll's work (1963) is used to identify specific features of teaching which, through their exaggeration, could perhaps best meet the present learning state of non-academic students. Bloom's work has already been used to conceptualize <u>how</u> exaggerations might be made, and the reader is now presented with a conceptualization of what teaching features could be emphasized.

The "Learning State" of Non-academic Students: Carroll

Use is now made of Carroll's model of school learning (1963) to provide the necessary conceptualization of teaching strategies which, if exaggerated, would be consistent with the learning needs of non-academic students. From the model, the investigator uses Carroll's definitions of "ability to understand instruction" and "quality of instruction". Carroll introduces the terms as two factors that might be involved in determining the degree of learning that occurs.

"Ability to understand instruction" is thought of as interacting with the method of instruction in a special and interesting way. This variable is described as follows:

> The ability to understand instruction could be measured, one would suppose, as some combination of "general intelligence" and "verbal ability"; the former of these two would come into play in instructional situations where the learner is left to infer for himself the concepts and relationships inherent in the material to be learned, rather than having them carefully spelled out for him, while the latter would come into play whenever the instruction utilized language beyond the grasp of the learner. (p. 726)

With regard to "quality of instruction," Carroll proposes that it is the teacher's job to organize and present the task to be learned in such a way that the learner can learn it as rapidly and as efficiently as possible. In order to do so, the learner must be told, in words he or she can understand, what he or she is to learn and how he or she is to learn it. Carroll suggests that the learner must therefore be put into adequate sensory contact with the material to be learned and the various aspects of the learning task must be presented in such an order and with such detail that, as far as possible, every step of the learning is adequately prepared for by a previous step. In addition, it may also mean that the instruction must be adapted for the special needs and characteristics of the learner, including his or her stage of learning. Carroll perceives that this variable applies not only to the performance of a teacher but also to the characteristics of textbooks, workbooks, films, teaching-machine programmes, etcetera.

Carroll postulates that the ability to understand instruction interacts with the type of instruction. If the quality of instruction is less than optimal it is possible that the learner will need more time to learn the task than he or she would otherwise need. In Carroll's opinion, some learners will be more handicapped by poor instruction than others, and the extent of this handicap is conceived to be a function of the learner's "ability to understand instruction."

> Learners with high ability in this respect will be able to figure out for themselves what the learning task is and how they can go about learning it; they will be able to overcome the difficulties presented by poor quality of instruction by perceiving concepts and relationships in the teaching materials which will not be grasped by those with lesser ability.
>
> For the purposes of this conceptual model, we shall say that the amount of time actually needed by a person to learn a given task satisfactorily is a function not only of aptitude (as defined previously), but also of the quality of instruction in so far as it is less than optimal. And the amount of additional time he will need is an inverse function of his ability to understand instruction. (p. 727)

For the purposes of this study, Carroll's work is important because it draws to one's attention the fact that the learner's "ability to understand instruction" interacts with the type of instruction. It has enabled the investigator to identify certain critical features related to the learning of any task and consequently to the teaching of that task. These features, if not mentioned by the teacher, will not be perceived by students with lower ability, and this again supports the investigator's argument that non-academic students benefit from having certain features of the teaching/learning task emphasized.

This constitutes the final step in the investigator's systematic conceptualization of teaching as it relates to the learning needs of non-academic students. From this work the following analytic scheme is presented.

Statement of the Analytic Scheme

The investigator began by using Bloom's work (1976, 1981) to bring to the reader's attention the fact that if both academic and non-academic students are provided with exactly the same instruction, the end result will be a normal distribution on an appropriate measure of achievement. If, however, students are provided with "favourable learning conditions," then it becomes possible to improve the achievement of the non-academic students. In order to understand what constitutes these "favourable learning conditions," the investigator began to develop a systematic conceptualization of the teaching that "works" for these students, teaching that accommodates their learning characteristics.

Hirst's work was used to establish the fact that two necessary conditions must be satisfied before an activity may be called a teaching activity. These two publicly observable features are: (1) the teacher must make clear what he or she intends to be learned, and (2) the teaching activity must take place at an appropriate level so that the pupil can understand what it is intended he or she should learn. However, it was pointed out that Hirst characterized teaching in general and that although Hirst's features of teaching are the same for both academic and non-academic students, these features need to be exaggerated for non-academic students. It was argued that without such modifications, non-academic students will experience little academic success. Consequently, the investigator began to conceptualize the modifications necessary in order for teaching strategies to be consistent with the learning needs of non-academic students.

Bloom's definition of "cues" was presented in order to clarify the first feature mentioned by Hirst. Cues include instruction as to what is to be learned as well as the directions as to what the learner is to do in the learning process. This provided an insight into how features of classroom teaching might be exaggerated. The use of Carroll's conceptions of "ability to understand instruction" and "quality of instruction" provided an insight into specific teaching strategies which, if emphasized, would best meet the present learning state of non-academic students.

From this conceptualization of the teaching which non-academic students need in order to learn, it seems possible to identify pedagogical features which, if stressed, have the potential to enhance the learning outcomes for these students. The investigator categorizes these features in the following way, and the five points constitute the analytic scheme developed for the present study.

Indicative features of teaching.

1. Instruction as to what is to be learned.
2. Directions as to what the learner is to do in the learning process.

Meeting the present learning state of the students.

3. Clarity, specificity and completeness of the concepts and relationships inherent in the material to be learned.

4. Teacher language which is within the grasp of the learner.

5. Adequate preparation for each step of the learning.

Summary

In this study the methodology being used is aimed at finding ways to detect the presence or absence of an emphasis on certain features of teaching in a non-academic science classroom. Towards attaining this goal, the investigator has carried out in this chapter a systematic conceptualization of the features being looked for and this has resulted in the pertinent features being classed into certain categories. The research methodology requires that this theoretical perspective now be translated to the context of the non-academic science classroom and so in the following chapter this set of categories, the analytic scheme, will be used to develop a set of criteria for identifying practical instances of an emphasis on these pedagogical strategies. This development is based on analysis of three science lessons taught by the investigator and it results in a set of empirically derived clues that comprise the "clue structure" for the study. Further elaboration of this process follows immediately in Chapter Four.

Chapter 4

ANALYSIS OF THE DATA

The previous chapter presented a theoretical perspective on teaching that is consistent with the learning needs of non-academic students. Consistent with the research methodology proposed by Roberts and Russell (1975), this must now be translated to the context of science education. In this study this particular step entails translating the theoretical perspective to the context of the non-academic science classroom through the development of a clue structure. The clue structure makes the identified theoretical perspective applicable to the phenomenon to be studied (in this case, the quality of interactions in the classroom), and moves the research from the realm of the theoretical to that of the practical, resulting in a systematic examination of the practical events. To accomplish this, use is made of the analytic scheme that was developed and presented in the previous chapter to derive a set of empirically determined clues through analysis of the data.

The analytic scheme comprises theoretically derived pedagogical features which, if emphasized or exaggerated, have the potential to enhance the learning outcomes for non-academic students. This analytic scheme was developed from the systematic conceptualization of the process of teaching and the accompanying realization of _how_ and _what_ features of teaching might be exaggerated in order to meet the learning needs of non-academic students. This analytic scheme is now used in the data analysis, acting like a "set of lenses" through which to view the data, determining what is looked for. As a result of this analysis the investigator derives a set of criteria, called a "clue structure," for identifying practical instances of the events. The research methodology has been designed to detect systematically certain pedagogical features and it is the clue structure which makes possible this detection.

The data for this study consisted of transcriptions of eight sequential lessons of sixty-five minutes duration which were taught by the investigator to a class of Grade 10 students. The teaching occurred over a three week period toward the end of the school year and it involved a science unit dealing with the topic of "Fire." Although all of the lessons were analysed in the course of the study, three lessons were especially informative and these have been chosen (plus a small excerpt from Lesson 4) for detailed analysis and presentation. The names of the pupils participating in the lessons have not been used in order to ensure the pupils' anonymity.

The chapter describes the development of the clue structure from the original analytic scheme through analysis of the data (Analysis I) and this is followed by an interim summary presenting a statement and explanation of the clue structure. The final portion of the chapter deals with a second analysis of Lessons 2 and 3 (Analysis II), concentrating on the "argument patterns" used by the students. This second analysis does not refine the clue structure already developed but serves a different purpose. The five points of the analytic scheme are all features of the teaching but it is argued that it is important also to provide evidence that the students are in fact experiencing success in learning. The second analysis is therefore used to illustrate the amount of student participation in the lessons and student understanding of the concepts involved.

Some Methodological Comments

The theoretical perspective resulting from Hirst's characterization of teaching and the conceptualization of "quality of instruction" and "ability to understand instruction" provided by Bloom and Carroll led to the development of a set of categories that could be used for analysis. Theoretically derived pedagogical features were identified which, if emphasized, have the potential to improve non-academic students' achievement. These features were categorized in the following way:

Indicative features of teaching.

1. Instruction as to what is to be learned.
2. Directions as to what the learner is to do in the learning process.

Meeting the present learning state of the students.

3. Clarity, specificity and completeness of the concepts and relationships inherent in the material to be learned.
4. Teacher language which is within the grasp of the learner.
5. Adequate preparation for each step of the learning.

The investigator's next task is to examine lesson transcriptions and derive criteria (clues) for detecting instances of an emphasis on these pertinent pedagogical features. The purpose of developing the clue structure is that it enables one to answer such questions as, "How would I recognize that the teacher is providing instruction as to what is to be learned?". In the following account of the analysis, seven clues are derived, each one related empirically to a specific teaching strategy exemplifying an emphasis on one of the categories of the analytic scheme. The development of the clue structure is the task of Analysis I, which follows immediately. It should be noted that the clues do not emerge in an order consistent with that of the categories in the analytic scheme. The clues have been labelled A to G; as each clue emerges from the data, reference is made to the corresponding theoretical category from which it was derived. At the end of the analysis, in the statement and explanation of the clue structure, the correspondence between the clues and the analytic scheme is emphasized.

Analysis I: Development of the Clue Structure

As noted earlier, the lessons have been analysed from two different perspectives. This first analysis shows the development of the clue structure, each clue identifying a pedagogical strategy used by the teacher. An asterisk denotes that additional written information is being provided to the students, either on the blackboard or in the form of information sheets. Such information is found in the appendix. Students are identified by number only (S1, S2, etc.) in the transcripts, and the teacher is identified as "T."

Clues Apparent in Selected Portions of Lesson One

Lesson 1 introduces the students to the topic of "Fire," the unit of work with which they are to be involved for eight lessons. The portions of the lesson presented below, together with a column of analytical comments, consist entirely of teacher utterances. Discussion of clues, as they emerge, is interspersed at appropriate points.

Transcript

T: The topic that we're covering is fire. I think all through the years . . . you know ever since the cavemen who found that they could make things burn, man has had a fascination with fire. So it usually is something that people are interested in. They like to find out as much as possible about it--what causes fire, how to prevent fire, how to extinguish fires once they start, . . . ah, this kind of thing. How to escape from buildings that are burning, how to make clothes fire retardant so that they don't burn, particularly night clothes and that type of thing. If you look at the topics that we're going to be covering . . . we're going to be looking at most of those things that I've just mentioned. I've listed that we're going to start off by looking at an historical view of the burning process. Over the years, scientists who have studied fire have tried to explain what happens when things burn. We're going to look at the different ideas that they've put forward and see if we can find anything wrong with them, or whether they're perfectly acceptable explanations. We're going to compare different substances burning. You know that some substances will burn a lot more easily than others. I'm going to give you samples of drapery material, carpeting, wood, plastic . . . all different fabrics and I'd like you to find which ones burn easily, which ones burn slowly . . . and which ones don't burn at all. Ah, we're going to look at the conditions that are needed for the burning process to occur. We're going to look at different ways of putting out fires. We're going to investigate some of the injuries and deaths that result from fires. We're going to look at common causes of explosions . . . how you can prevent those explosions from taking place. We're going to see if you can recognize hazardous situations at home . . . at school . . . see if you can reduce the chance of fire or explosion taking place. And then we're going to see if we can make flammable materials fire resistant. So I'm going to give you bits of fabric, have you treat them certain ways and see whether or not you can prevent them

Analytical Comments

CLUE A:
overall perspective and objectives. As an introduction to the unit on "Fire" the students are told what is to be learned in the coming month, and a printed sheet titled "Topics to be covered" is handed out to the students at the beginning of the lesson.

from burning. Now that's just an overview of what we're going to be doing. (A student drops her pencil.) Settle down. That's what we're going to be doing in the next month.

CLUE A again: teacher has presented eight topics for study.

* The teacher spends some time compiling a chart of information on the topic of fire provided by the students. The first activity is then introduced (it is labelled "Activity 2" in the student materials).

CLUE A again: overall objective for Activity 2.

* On the Activity 2 sheet, students are provided with the purpose of the activity. This information is also written on the blackboard.

Clue A has emerged from the data at the very beginning of Lesson 1. The lesson begins with the teacher telling the students what is to be learned in the coming month, and reinforcing this information with a printed sheet. When Activity 2 is introduced the teacher emphasizes the objective involved by handing out an information sheet on which the purpose is printed, and at the same time the purpose is written on the blackboard. <u>**CLUE A**</u>, then, can be stated thus:

Provision of an overall perspective of the work to be covered and the objectives involved (verbal and/or written).

The lesson transcript continues now from the point where it was interrupted above.

T: Now, the first activity . . . over here, you put down what you think happens during burning. As I mentioned right at the beginning, over the years scientists have had a lot of different ideas or explanations as to what they think happens when a substance burns. They put forward an idea or an explanation. They say, "Okay, I believe that when burning takes place, this is what's happening." That's their idea, or theory, to explain burning. Now, one scientist . . .

CLUE F: the term 'theory' is defined before the phlogiston theory is introduced.

whose name was Stahl S-T-A-H-L . . . he put forward what was called the phlogiston theory to explain burning. And he said this: He said that he thought that when something was burned, something was given off from the burning substance. And he decided to call it . . . whatever was given off . . . phlogiston. Okay, that's how you pronounce it . . . phlogiston. He said that things burned because they contained this substance called phlogiston . . . and when you burned it, all the phlogiston was given off and it went into the air. If a substance didn't burn, he thought that the reason was that . . . the substances that didn't burn didn't contain any of this phlogiston to start off with. So if they didn't have any phlogiston . . . then they wouldn't burn. If they did possess phlogiston, then when you burned, all of this substance is given off into the air. And so he believed that things would get lighter as you burned them 'cause all the phlogiston was given off. He thought that the air around the burning object couldn't hold a limitless supply of phlogiston. So after a time . . . when the air around the object was full of phlogiston, then the burning process stopped . . . because the air couldn't hold any more of this phlogiston. Now that was his idea . . . what he thought happened during the burning process. It had phlogiston . . . it burned. It gave it off into the air. Once the air was completely saturated, or full, of this phlogiston . . . the burning stopped. Okay. This was his theory or explanation.

<u>Phlogiston Argument</u> (see explanation below). Teacher provides the Backing and Warrant to be used in the Phlogiston Argument. Illustrates completeness of material in teacher presentation.

Backing.

Conclusion.

More Backing.

CLUE E: teacher has provided the basic structure of the Phlogiston Argument.

At the beginning of the above section of transcription a clue emerges about "teacher language which is within the grasp of the learner." This clue emerges more strongly in Lessons 3 and 4 and in order to demonstrate this, specific portions of these two lessons are presented in the final portion of Analysis I. However, in the present section what is apparent is that the teacher defines the term "theory" before presenting Stahl's phlogiston theory of burning. **<u>CLUE F</u>** is therefore presented as:

Definition of new terms before use.

The clue to be developed about the "completeness of material" and the analytical comments above about "the Phlogiston Argument" require an introduction to an analytic device developed by Stephen Toulmin (1958), called an "argument pattern." Toulmin distinguishes between the claim or conclusion (C) whose merits one is trying to establish and the facts one appeals to as a foundation for the claim, referred to as the data (D). The step from the data to the original claim or conclusion is an appropriate and legitimate one if a proper "warrant" (W) justifies the move.

If the acceptability of the warrant is questioned, Toulmin points out that one can use statements called "backing" (B) to defend the warrant. However, the backing for a warrant may often remain implicit, the warrants being accepted without challenge and their backing left understood. The "argument pattern" includes two additional features: (1) "modal qualifiers" (Q), which indicate the degree of force with which the data support the conclusion, and (2) "conditions of exception or rebuttal" (R), indicating conditions under which the general authority of the warrant would be negated. These two features have not been used in the (forthcoming) analysis, and so the modified version of Toulmin's "argument pattern" can be summarized as shown in Figure 1.

D ⟶ So, C

Since W

On account of B

Figure 1. Toulmin's Argument Pattern (Modified)

In the portion of transcription directly above, the following argument (Figure 2) has been identified in the teacher's commentary. Note that the conclusion is an explanation in terms of the basic postulates of the theory (which constitute the backing); the warrant expresses how the basic postulates "work" to produce the explanation.

Data
An object that burns becomes lighter and eventually stops burning.

Conclusion
The object gives off its phlogiston while burning. The air around it becomes saturated with phlogiston eventually.

Warrant
When an object burns, phlogiston is given off. When the air around the object is saturated with phlogiston, the burning stops.

Backing
Objects that burn contain phlogiston. The air surrounding a burning object can hold only a limited amount of phlogiston. When saturated with phlogiston, air can no longer support combustion.

Figure 2. Basic Structure of the Phlogiston Argument

Since the teacher has taken care to supply all of the components of the argument, the judgement is made that there is complete presentation of the material to be learned--that is, the concepts and relationships inherent in the material are specified. CLUE E is therefore stated as:

Provision of the data, warrant and conclusion to arguments.

The lesson transcription again continues from the point where it was interrupted above.

T: Now, in this particular activity what I want you to do is to do three experiments to do with burning. And I want you to see if after you've got your results, you could use the phlogiston theory to explain what you noticed happened. We want to compare different ideas. In Activity 2 it will give you two conflicting ideas. One is the phlogiston theory. And then there's a second one at the end of the book . . . at the end of the unit. I want you to compare those two different ideas that the scientists put forward about what happens during burning. We accept a theory, or an idea as to what happens . . . if it will explain the results that we get. So we would say it's a good theory if we find that it would explain what we've seen happen. We would think that it's a fairly poor theory if all of a sudden we came across facts that we couldn't explain.

CLUE B: function of this section of work. Teacher provides the reasons for doing the three experiments.

CLUE E: Teacher introduces the Theory Acceptance Argument.

CLUE E: teacher presents Theory Rejection Argument.

In this portion of the transcription a new clue has emerged as the teacher proceeds to explain the reasons why the students are to perform the three experiments. The function of the work will be repeated twice throughout the lesson, as will be seen when the final portion of the Lesson 1 transcription is presented below. **CLUE B**, dealing with "instruction as to what is to be learned," can therefore be stated as:

An emphasis on the significance/function of the individual parts of the instruction sequence (verbal and/or written).

It will be noted that CLUE E emerged once more when the "Theory Acceptance Argument" was presented completely: data, warrant, and conclusion (backing came earlier). The argument can be summarized as shown in Figure 3.

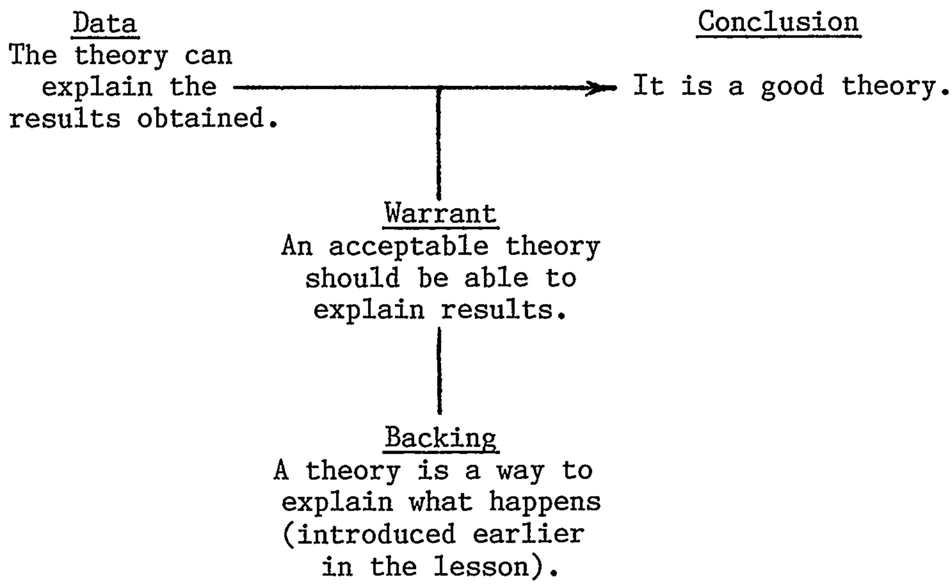

Figure 3. Basic Structure of the Theory Acceptance Argument

Conversely, a "Theory Rejection Argument" was also presented, as shown in Figure 4.

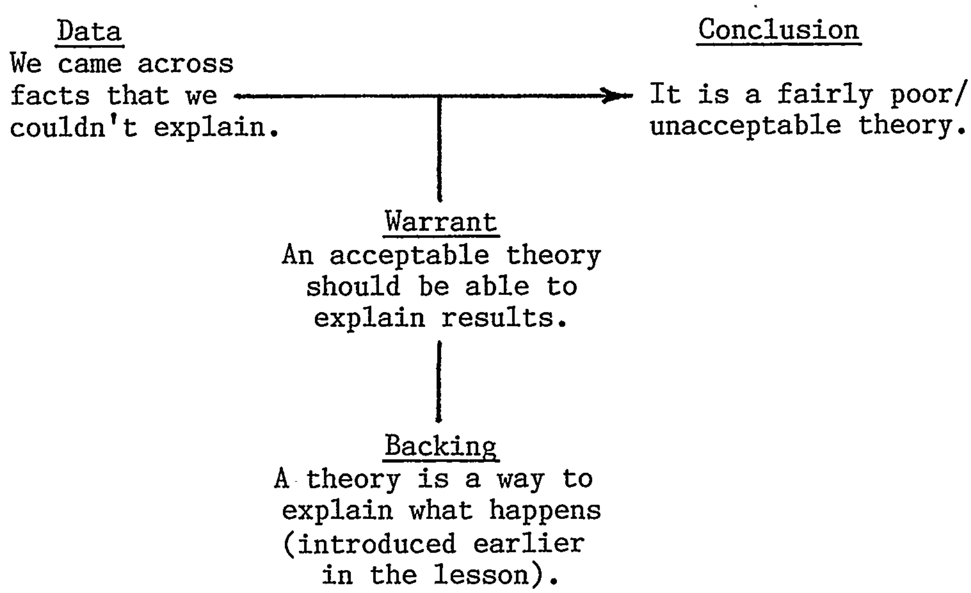

Figure 4. Basic Structure of the Theory Rejection Argument

Lesson 1 reaches a conclusion in the portion of the transcription which follows.

T: So what I want you to do is three things. They're very simple and they don't take long. I want you to cover a burning candle by a beaker . . . make sure it's larger than the candle. I want you to record the observations and then I'd like you to see if you could explain what happens in terms of the phlogiston theory. The second thing I'd like you to do is I'd like you to weigh the small candle, burn it for ten minutes, and reweigh it. And when you've jotted down the measurements off the balance	CLUE D: variety of cues. * As the teacher describes the steps to be followed, she points to the blackboard where the same instructions are written.
. . . see if you can explain what happened during the process using this phlogiston theory. And then I've got one last thing for you to do. I'd like you to weigh some steel wool, burn it, and then reweigh it. I'd like you to put down your observation . . . the measurements you know, the mass before and after . . . and then	CLUE B: function of the work. Students are to explain results using phlogiston theory.
again, see if you can explain what happened during the burning process using the phlogiston theory. Now, I've told you what it involves. You'll find it also explained in the book. So	CLUE B: function repeated.
what you have to remember is his theory was . . . something that contains phlogiston will burn. As it burns, all the phlogiston will be given off, and so you'll end up with something that is lighter than it was to begin with. Something will stop burning as soon as the air around the substance is full of phlogiston. So what you do is you do three simple experiments to do with an object burning.	CLUE E: repeats Backing and Warrant for the Phlogiston Argument.
You put down your experimental results . . . and then you see if this particular theory can explain them. If it can, it's a good theory. If you can't explain it, then the theory is perhaps debatable. There might be something	CLUE B: repeats function. CLUE E: repeats Theory Acceptance Argument.
wrong with it. Now that's what you've got to do . . . so I'll leave that on the board. What you need is this. The candles that we're using are these small birthday candles. I've got lots of them (goes on to show the materials, repeat the directions, and give safety reminders).	CLUE D: repetition of instructions, verbal and written cues, and demonstration of what is to be done.

The section of the transcript above not only reveals repetitions of clues B and E, but also reveals a new clue about the "directions as to what the learner is to do in the learning process." As the teacher gives directions involving the three experiments, a variety of cues are presented to the students. The directions are given verbally and at the same time these directions are in written form on the blackboard. The instructions are repeated and the steps involved are demonstrated by the teacher. A statement of CLUE D is thus:

Use of a variety of cues to help the student understand the steps that are to be followed. Examples: repetition of instructions, use of both written and verbal instructions, description and demonstration of the steps to be followed.

Clues Apparent in Selected Portions of Lesson Two

As with the discussion of Lesson 1, transcribed portions of Lesson 2 (with a column of analytical comments) are interspersed with discussion of the clues which emerge. In this case there are several speakers, so "utterances" (complete for each speaker, rather than single sentences) are numbered sequentially for reference in the discussion.

1 T: Okay, I'd like you to open your books to Activity 2, and we'll try and interpret what information you got. I've left this on the board . . . you don't have to copy it down. It was just to remind us of the purpose of the exercise . . . what we're going to try and do with these things (assists a late-coming student)	CLUE A: overall objective for Activity 2. * On the blackboard is written the purpose for Activity 2.
2 T: Okay, Activity 2. (student giggles) Let's quieten down. (S6) can you turn around please?	
3 S6: Sorry.	
4 T: Okay, what we were trying to do yesterday, we started off and we pooled all the ideas about what we knew so far about burning, fire, etcetera. And then we started off and we're looking now just at the process of burning. And we're trying to	CLUE G: links information. Teacher reminds students that the topic being discussed is the

sort out what ideas have been presented over the years about what happens when a substance burns. You gave me some ideas of what you thought happened. What we're doing now is we're going back . . . we're looking at ideas that scientists have presented in the past. And in particular, we're looking at an idea which is called the phlogiston theory. It was a scientist called Stahl S-T-A-H-L. He thought that he could explain burning by proposing his phlogiston theory.

process of burning, moving from the students' ideas to the ideas put forth by Stahl.

The lesson began with the teacher reminding the students of the overall objective involved in Activity 2 by pointing to the blackboard, on which is written the purpose of the activity (CLUE A). However, in utterance 4 a new clue emerged as the teacher links the work from Lesson 1 with the present work. It is interesting to note that this clue becomes more apparent in subsequent portions of the transcription, as increasing amounts of new work are presented to the students. **CLUE G**, relating to "adequate preparation for each step of the learning," is stated as follows:

An emphasis on how pieces of information fit together by linking previous work to new work related to it.

Utterance 4 is completed, and the lesson continues.

T: First thing I want to ask you . . . can anybody tell me any parts of the phlogiston theory? How would he explain burning. (pause) Yes (S12)?

5 S12: The substance that leaves is called phlogiston?

6 T: The substance that leaves is called phlogiston. Anything else . . . (S3)?

7 S3: All things that burn have phlogiston in them.

CLUE C: summary of the key concepts. Teacher asks for a summary of the phlogiston theory.

8 T: All things that burn have phlogiston in them. (S6).

9 S6: When the fire goes out there's a concentration of phlogiston cutting off the air supply?

10 T: Right, good. That's another bit of information. That when something stops burning . . . how did you phrase that again . . . there's a concentration of phlogiston cutting off the air supply. Okay. So those were essentially what he believes happens during burning. All substances that burn have this element called phlogiston. It's given off during burning. When the air can't hold any more, then the thing stops burning. Now that's his theory. What you're doing is trying to see whether or not that's a good theory. And so my question is . . . how do you know as a scientist or just as . . . you know a normal everyday person on the street . . . how do you know whether or not a theory is a good one or not? How do we know whether we should accept this phlogiston theory of burning? (S9)?

CLUE C again: summary of key concepts. Teacher summarizes Phlogiston Argument.
CLUE B: function of the work.

CLUE C again: teacher asks students to summarize Theory Acceptance Argument.

11 S9: If it works on a numbers of experiments and tests. But I don't see how this could work on say a forest fire.

12 S3: Because of the air supply?

13 T: So you're saying that it would be considered to be a fairly good theory as to what happens during burning if . . . now just say that again . . .

14 S9: Well, if you have a candle burning and all of a sudden it goes out, and there's no more phlogiston left, then all the air . . . all the phlogiston's composed of the air . . . then how come in a forest fire . . . you know, just because it's a greater expanded area doesn't mean that there's more air . . . limitless. Do you understand what I mean?

15 T: Yes.

16 S3: Can't put a beaker over though.

17 S9: It's just hard to believe.

18 S3: You can't put a beaker over top of a forest fire though.

19 S9: I know . . . I don't know . . . I just can't . . .

20 T: Yeah. When do you start doubting whether a theory is good or not?

21 S9: When it fails.

22 S2: If it doesn't work in all experiments?

23 S3: You put it to work.

24 T: Yeah. If you find that it doesn't really adequately explain your results, then you start thinking, well maybe this isn't such a good theory after all. So that was why I had you do three things yesterday. So we want to see what kind of results you got. And you tell me whether or not we could adequately explain them. Uh . . . the first one . . . the burning candle covered by a beaker. Okay we'll come back to that. Uh . . . the next two . . . you were supposed to weigh the small candle . . . burn it for ten minutes . . . that was too long . . . and then reweigh it. What I would like is I would like the data that you got from each group.	CLUE E: Theory Rejection Argument. CLUE G: links information. Teacher reminds the students that they are going to judge the acceptability of the phlogiston theory based on its ability to explain the results.
Somewhere you should have put down how many grams it was before and after burning. And the same thing for the steel wool. You weighed it before and after burning. So what I'm going to do is I'm just going to call on each lab group and I'd like you to tell me what information you did get just so that we can have a look at them collectively. For the candle (S13) you were jotting it down again. Have you got the measurement for the candle before and after burning?	CLUE D: variety of cues. * Written work on the blackboard emphasizes what the students are to do.
	Students then collect data for the candle burning and try to explain the results for the first and second experiments using the phlogiston theory. Data are then collected for the steel wool burning.

In the portion of the transcript above, a third and final clue emerges about "instruction as to what is to be learned." In utterances 5-9 the key concepts of the phlogiston theory are summarized, and then at the end of utterance 10 the teacher asks for a summary of the Theory

Acceptance Argument. This summary is provided by the students in utterances 11-23. <u>**CLUE C**</u>, then, is stated thus:

Summary of the key concepts by the teacher and/or students in a verbal and/or written manner.

In addition to showing the emergence of Clue C, the transcription illustrates how the teacher repeats the Theory Acceptance Argument (CLUE E) before linking the argument with the experiments performed in the previous lesson (CLUE G). This is followed by the use of a variety of cues explaining what the students are to do with experimental results--written work on the blackboard reinforces the verbal instructions given (CLUE D).

Each of the seven clues comprising the clue structure has now emerged from the data. In the remaining portions of Analysis I, repetitions of these clues will be evident but attention will be directed towards the different argument patterns being used and the distribution of the clues in different portions of the lessons.

In the following portion of Lesson 2 (after data collection, noted earlier), students are asked to use the phlogiston theory to explain the experimental results for the steel wool burning.

25 T: (writes) Okay, so now looking at the third one then . . . the steel wool is weighed, burned, then weighed again. You have to record your observations . . . (S7), how would you sum up the observations from all the different groups?

26 S7: The steel wool is getting heavier.

27 T: Yeah, the steel wool is getting heavier as it burns. So those are the observations. Now you've got to try and explain those results using the phlogiston theory.

Data for the <u>Phlogiston Argument about Steel Wool.</u>
CLUE B:
function of the work.

28 S3: Phlogiston from the burning matches is attaching to the steel wool.

29 T: The phlogiston from the burning match is attaching to the steel wool.

30 S9: Causing a build-up on the steel wool.

31 T: Causing a build-up on the steel wool . . . of phlogiston?

32 S9: Yeah.

33 T: Okay. Anything else you'd like to offer as a way of explanation. 'Makes sense? Yes?

34 S6: If there's a build-up on the steel wool of phlogiston . . . and the phlogiston is supposed to burn . . . then how come you couldn't light it again?

35 T: Very good point.

36 S9: (inaudible)

37 T: That's a possible explanation.

38 S2: What did she say?

39 T: (S3) said that the phlogiston builds up on the steel wool . . . and that's why it gains weight. (S6) pointed out that phlogiston is supposed to burn . . . and yet you kept putting the matches to it, and eventually, it stopped burning. That was when you were supposed to stop.

CLUE B: teacher emphasizes significance of what students have said in sequence, clarifying function of the work.

40 S3: But if you keep putting the match to it, you're still putting on phlogiston.

41 T: And then (S9) offered the possible explanation that maybe once it's burned once, it won't burn a second time. Yeah.

42 S8: But with the candle, it would still burn a second time.

43 T: That's true. Yes (S6)?

44 S6: That wasn't explained in the theory was it?

Student judges the Phlogiston Argument.

45 T: Sorry?

46 S6: That wasn't explained in the theory.

47 T: It wasn't explained in the theory, no.

48 S6: So . . . that's not really . . .

49 T: Whenever you get . . . yes (S9)?

Discussion of Phlogiston Argument about Steel Wool comes to a close. Teacher provided Warrant and Backing, students collected Data. Students uneasy about Conclusion reached.

50 S9: Maybe only the wool holds phlogiston . . . and after the phlogiston in the wool is burned off, . . . the steel wool won't light fire.

51 T: Yeah, you've got another possible explanation. Whenever you get to a point like this, where it gets harder and harder to come up with an explanation that seems to fit . . . then you start asking yourself whether or not this theory is perfectly acceptable. Good. I like your ideas.

CLUE E: Teacher reminds students of the Theory Rejection Argument.

The portion of the lesson just presented illustrates well how the students continue discussion until they have produced an argument that is acceptable to them. (This discussion will be re-analysed in Analysis II.) The students' uneasiness with the Phlogiston Argument can be seen readily in the arguments represented as Figures 5 and 6.

Data
Experimental results show steel wool gains mass.

Conclusion
Phlogiston theory cannot really explain the results.

Warrant
Whenever phlogiston departs from burning substances the residue weighs less.

Backing
From phlogiston theory: phlogiston is given off during burning.

Figure 5. Phlogiston Interpretation of the "Steel Wool Burning" Experiment

Data
Phlogiston theory can't explain results.

Conclusion
Phlogiston theory is not an acceptable theory.

Warrant
An acceptable theory can explain results.

Figure 6. Judging Phlogiston Theory by the Theory Rejection Argument

The presentation of Lesson 2 now continues from the point where it was interrupted above. The following material brings the lesson to completion.

T: What I would like you to do . . . there's another theory put forward in the book as well. And what I would like you to do is I would like you to work through Activity 2, answering these questions, and also coming across another theory put forward. I'll just put the name on the board. You'll find another scientist's name . . . called Lavoisier (writes) . . . and he's got another idea as to what happens during burning. What I would like you to do now is I would like you to work through the questions using the phlogiston theory, and then I'd also like you to put down this second theory about what happens during burning. And when you've got all those questions answered, we'll see whether or not we agree or disagree about the theories . . . which ones we think are better . . . and which we think are worse. Now when we say better or worse, we just mean which ones seem to explain the results more adequately. So in Activity 2, work through right the way to the end of the questions. And if you have any problem with the question at the end, which is the law of conservation of mass, leave it . . . and I'm going to show you a film when you've finished the questions and that might help you answer the very last one. So either by yourself or in your group, will you just work through the questions to do with the theories. And when you're ready, we'll discuss it, and I'll show you a film just to tie everything in together. Okay, I don't

CLUE B: function of the work. Teacher explains what will be done with information collected.
CLUE E: teacher repeats Warrant for Theory Acceptance Argument.
CLUE D: variety of cues. Instructions being repeated.

think that will take too long 'cause I think most of you were working through the questions as you did it yesterday. Let me know if you have any problems and as soon as you're ready, I'll show you the film.

(The students are given 15 minutes to work on the questions.)

52 T: Would you just finish the answer that you're writing at the moment? (pause) You told me at the beginning of the lesson what the phlogiston theory of burning was. Now that you've got through to the end of that particular section, you've come across an alternative theory. You've come across Lavoisier's oxygen theory. Now, just as you told me what's involved in the phlogiston theory, tell me what he believes happens when something burns. Yes (S5)?

CLUE G: links information. Teacher reminds students that two theories are being compared.

Students provide information about the oxygen theory.

53 T: Okay, right. Let's show the film. This is a short film . . . this is to do with combustion . . . an introduction to chemical change. (applause) This is to do with the oxygen theory . . . so you can decide after seeing this whether you believe this one or the other one.

CLUE B: function of the activity.

54 S5: I believe the oxygen theory.

(The film is roughly 10 minutes long.)

55 T: Could we get the lights? So . . . oxygen theory. When everything burns, it combines with the oxygen in the air to give you a new product. What they didn't show on the film was if you could weigh the oxygen in a sealed container with the chemical . . . and you weigh it before and after burning . . . then there will be no change in mass. But they did no experiment throughout there where they had a sealed container so they could weigh the oxygen and the substance together at the beginning and the end. According to Lavoisier, if you do that in a sealed container there will be no change in mass. Any questions about any of those that you're trying to answer? Okay, what I'd like you to do then in the last 10 minutes is I'd like you to pick up this summary sheet for Activity 2. I'd like you to hand it in at the end of the lesson. Just answer those three questions and hand it in separately. I won't take in your duotangs today . . . there won't be enough done. But will you pick up this sheet and hand it in to me at the end of the lesson. It's only

CLUE E: Teacher summarizes oxygen theory as Backing to be used in a new argument.

CLUE C: summary of key concepts. A summary sheet is handed out with four questions to be answered.

three questions and I would like this handed
in before the end of the lesson.

The transcription above shows that as a new section of work is introduced, namely the oxygen theory of burning, clues relating to "instruction as to what is to be learned" (CLUE B) and "directions as to what the learner is to do" (CLUE D) emerge from the data. At the same time CLUE G is evident, as the teacher links the previous work to this new information. As the lesson comes to a close, however, CLUE C (summary of key concepts) is the predominant one.

Clues Apparent in Selected Portions of Lessons Three and Four

Selected portions of Lessons 3 and 4 are presented below, to illustrate other facets of several of the clues already developed. In these cases the utterances are not numbered, since there is no need to refer to them specifically in the text.

T: Don't forget I didn't correct the duotangs because there wasn't really enough to do. We're just working on Activity 2 at the moment. I did mark the pink summary sheets that you did. And just before I hand them back, again, I'd just like to read out some answers that were really good that you wrote on these. So just finishing off Activity 2 . . . Okay, these were the four questions . . . I gave you a mark out of eight for them.	CLUE C: summary of key concepts. Teacher uses student answers to emphasize the key concepts to be learned.

S12: (S7)'s at the door.

T: (lets him in) I'll just remind you that people who come late get to stay afterwards and make up the time that they've missed. Question number one . . . uh, the question that most of you asked was this one: "How did George Stahl explain the process of burning?" This one, I thought, was a really good answer. "Things that burn contain phlogiston. When a substance burns, phlogiston leaves the substance and goes into the air. Air can hold phlogiston, but when the air gets full of phlogiston, nothing more can burn in the air." So that summed up three bits of information, (S13), about phlogiston. Things that burn contain it . . . it leaves when it burns . . . when the air is full, nothing more can burn. Number two . . . two (a) said, "Why did Lavoisier think that the phlogiston theory was incorrect? Answer: "It couldn't explain the change of weight when there was a gain." (b): "What was Lavoisier's explanation for the burning process?" Answer: "All burning substances combine with the element oxygen. No mass is gained or lost, there are merely new combinations of materials." And the last question was, "How can one demonstrate that the law of conservation of mass applies to burning?" The answer was, "Place a substance in a sealed container and weigh it before and after burning . . . and the weight should be the same." So those, I thought, really summed up what we were trying to put down as a result of those. So I'll give you these back, and I'd like you to put them in your duotangs . . . and I'll record the mark next time when I take your books in at the end of the week. So don't lose them . . . put them in your duotang. (passes the pink sheets back while students compare their marks and commend each other.) Okay, so if you put those to one side so you don't lose them. And then what we're going to do is finish off Activity 2. Before I leave it, what I've done is I've just put on the board what I just read out from the sheet. We started off the unit by talking about the phlogiston theory of burning . . . and how it could explain your experimental results. On the board now, what I've written is the oxygen theory of burning. "All burning substances combine with oxygen. When there's no more oxygen, or for that matter no more substance, the burning process would stop." Now that's his explanation for what he thinks happens during burning. Today which do you think is more acceptable . . . or which do you think we do tend to accept? Do we * accept the phlogiston theory of burning?

CLUE C: the key concepts to be learned have been summarized.

CLUE G: links information. Teacher reminds students that the discussion has moved from the phlogiston theory to the oxygen theory.

CLUE E: part of oxygen theory.

CLUE D: written work reinforces discussion.

S's: Oxygen (together).

T: Or the oxygen.

S's: Oxygen.

T: Yeah, the oxygen theory. Have you any idea why we think that that's more acceptable than the phlogiston one?

S2: Because experiments prove that . . . uh, when there's no more oxygen the process stops.

T: So in other words, you could explain the burning process if you said that. Is that what . . . yeah. That one, substances do combine with oxygen . . . and then when there's no more oxygen the burning process stops. Okay, 'cause remember last time . . . uh, (S9), I think you explained it . . . what makes a good theory? Why do we say that something's a good theory or a bad theory?

S9: Well, you have to prove it with experiments . . . like it could have phlogiston and no oxygen and it would still not burn.

T: Okay. Yeah, what we were trying to do last time . . . we came up with a problem and you were giving me the explanation of these three sets of results last time. Uh, phlogiston theory explained this set of results quite well (points to "candle covered by a beaker"), it explained that set of results quite well (points to "candle burning") . . . but for the third one, that's where we ran into the problems. That's where we started to think that maybe it wasn't perfectly acceptable. Because, although you gave me some really good ideas about why the steel wool would weigh more after burning, it tended to get more and more complicated. So today, the reason we think that the oxygen theory is more acceptable is that it seems to explain the results a little bit more clearly. So, let's just go back and try and explain the three sets of results using this oxygen theory of burning.

CLUE G: links information. Teacher reminds students that the phlogiston theory couldn't explain the results. The students are then asked to use the oxygen theory in a similar way.

CLUE E: teacher presents <u>Theory Comparison Argument</u> (discussed below).
CLUE D: variety of cues.
* Written work on the blackboard reminds students what is to be done.

The students now offer explanations using the oxygen theory, and later in the lesson the following occurs.

T: Good, thank you. Good. So we've got two completely different theories of burning . . . the phlogiston theory and the oxygen theory. And this is the one that seems to be more acceptable because it seems that it can

CLUE E: Theory Comparison Argument repeated.

explain the results with less difficulty than the phlogiston theory. One thing I want to remind you about which you mentioned on the summary sheet that you handed in . . . don't forget that if I could have . . . or you could have done experiment 2 and 3 in a sealed container . . . if you could have weighed the candle and the air around it, there would have	CLUE C: summary of key concepts.
been no change in the weight. If you could have had a sealed container with your piece of steel wool . . . and you could have weighed the steel wool and the air around it before and after burning, then there would have been no change in mass. So don't forget that if you do have a sealed container and add the candle burning or the steel wool burning . . . if you could have weighed the candle and the air around it before and after, there would have been no change in mass. (S14), you had it on your sheet . . . you put down as your answer that if you started off with 10 grams of wood and air at the beginning, you would end up with 10 grams of ashes and gases	CLUE E: Teacher provides important bit of Data not accessible to students.
afterwards. If you have a sealed container, the law of conservation of matter would apply.	CLUE C again: key concept.

A number of clues are distributed throughout the excerpts just presented from Lesson 3. At the beginning there is a summary of the previous day's work regarding the phlogiston theory (CLUE C). As the lesson progresses, the transition is made from the use of the phlogiston theory to the use of the oxygen theory for explaining the experimental results (CLUE G). As this new work is begun, a variety of cues are used to remind students what is to be done (CLUE D). The latter portion of the transcription shows CLUE E and CLUE C emerging again, as the argument is completed and the key concepts summarized. Note that the "Theory Comparison Argument" is a new argument, represented in Figure 7; the theory comparison discussion will be re-analysed in Analysis II.

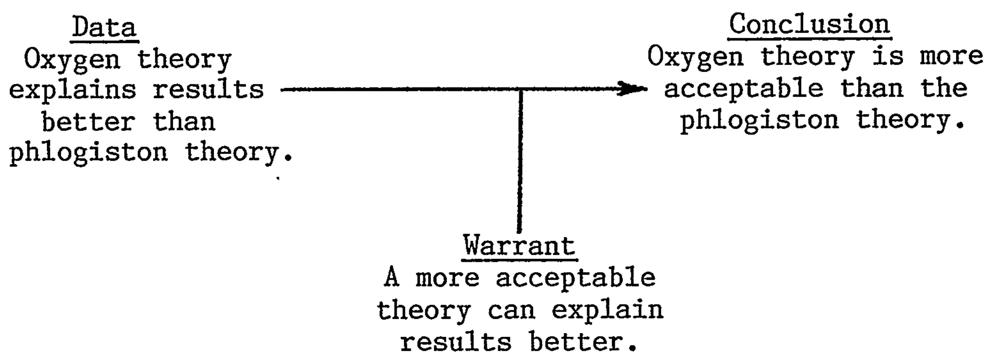

Figure 7. The Theory Comparison Argument

While a number of the clues have appeared repeatedly in the material presented so far, giving a variety of manifestations of each clue, Clue F **(Definition of new terms before use)** has not appeared since it was introduced. In anticipation of completing this section on development of the clue structure, here are brief excerpts from two lessons in which Clue F can be seen. First, at the end of Lesson 3, Activity 3 is being introduced by the teacher. The students are to test materials in order to classify them as "noncombustible," "combustible," and "flammable," at which point the following teacher utterance occurs.

> I think before I demonstrate the actual experiment what I'd like to do is just give you the definitions for those three terms. Noncombustible, combustible and flammable. So I'd like you to put a heading, "Background Information for Activity 3." I'm just going to define those three terms."

The second example is the only portion of Lesson 4 analysed, and is selected to show a slightly different aspect of Clue F.

T: Does anybody know what we mean by the term "ignition point"? What do you mean by the term "ignition point"?

S3: When it starts to burn.

T: Yes, the point at which it starts to burn. If you say that something has got a high ignition point . . . or a low ignition point, which do you think would be the one that would burn faster?

S's: High.

T: High ignition point, or low?

S's: Low.

T: Okay, how many people think a high ignition point means that it burns quickly? (pause) Uhmm, let me give you an example. If I say high ignition point, I may say 500 degrees (writes) . . . 500 degrees before it starts to burn. If I say that something's got a low ignition point of about 20 degrees . . . that's the temperature at which that one will start to burn. High ignition point . . . low ignition point. Which one do you think would burn more quickly?

S's: Low.

T: Yes. The term low ignition point means you don't have to heat it a long time, or to a high temperature before it starts to burn. With a high ignition point, you've got to keep heating it to a really high temperature before it will burn. The low ignition point ones burn faster. If you time it, what would the ignition time tell you? You know, if you timed how many seconds it took to catch fire?

S9: It would tell you how more easily combustible it is?

T: Yes, it would. Uh, . . .

S9: Or am I . . .

T: No, you're right. You're fine . . . yeah, combustible or flammable . . . it would tell you that. If you time it and it took three seconds to ignite . . . and you timed it and it took twenty-two seconds to ignite . . . which one's burning more easily?

S12: The three second one.

T: Right. Would that have the low ignition point, or the high?

S's: The low.

T: Yes, good. I'm going to give you three substances and I want you to compare the ignition points. And I'm going to ask you simply to record the time it takes for the three substances to burn.

It is evident that until the teacher provides concrete examples to the students they exhibit difficulty understanding the term "ignition point" and its relationship to "ignition time." This, of course, is one way teachers define terms and it therefore represents one of the manifestations of Clue F.

This concludes the development of the clue structure, and brings Analysis I to a close. What follows is a statement of the complete clue structure and further clarification of it, by way of an interim summary for this chapter.

Statement and Explanation of the Clue Structure

Analysis I has shown that an emphasis on the specific teaching features categorized theoretically in the analytic scheme can be detected using the following clues.

CLUE A. Provision of an overall perspective of the work to be covered and the objectives involved (verbal and/or written).

CLUE B. An emphasis on the significance/function of the individual parts of the instructional sequence (verbal and/or written).

CLUE C. Summary of the key concepts by the teacher and/or students in a verbal and/or written manner.

CLUE D. Use of a variety of cues to help the student understand the steps that are to be followed.

CLUE E. Provision of the data, warrant and conclusion to arguments.

CLUE F. Definition of new terms before use.

CLUE G. An emphasis on how pieces of information fit together by linking previous work to new work related to it.

There follows a review of the theoretical background from which the analytic scheme and the clues were derived. This section offers further explanation of the clues and, as well, serves as a bridge to Analysis II.

Hirst's characterization of teaching was used to identify two necessary conditions that a teaching activity must satisfy. In an attempt to elaborate upon the two publicly observable features mentioned by Hirst, the investigator used Bloom's definition of "cues" to clarify the first feature. Cues include instruction as to what is to be learned as well as directions as to what the learner is to do in the learning process. This information was used to develop the first two categories of the analytic scheme and when these categories were applied to the data, the investigator was able to derive four clues for detecting the presence or absence of an emphasis on these features. Clues A, B, C, and D in the clue structure are consistent with the definition of cues--Clues A, B, and C being concerned with what is to be learned while Clue D deals with what the learner is to do. Here is an elaboration of these four clues.

A: The students have an appropriate context within which the new work can be understood and the students are also made aware of the information that is to be learned.

B: The teacher makes clear to the students why the work is to be done and this once again brings to their attention what they are expected to learn.

C: It is important that the students are constantly aware of what they are being asked to learn and so a summary of key concepts focusses their attention on the most relevant facts.

D: This is an attempt to make as clear as possible the directions as to what the learner is to do in the learning process. The use of various cues increase the chance that the students will understand the directions being given.

Carroll's conceptions of "ability to understand instruction" and "quality of instruction" were used to provide an insight into critical features of any teaching/learning task. From this the investigator judged what features of teaching need to be exaggerated for non-academic students and this provided the necessary elaboration of Hirst's second condition, that the teaching activity must take place at a level appropriate for the students. Consequently, Clues E, F, and G refer to how the work can best be learned. An elaboration follows.

E: The teacher explicitly states the concepts and relationships in the material to be learned by presenting the students with a complete, logical argument (Further elaboration of this clue is provided below).

F: The teacher uses language that can be understood by the student.

G: The teacher provides for conceptual continuity by explicitly linking together related pieces of information.

CLUE E **(Provision of the data, warrant and conclusion of arguments)** merits special attention and comment at this point. A common characteristic of non-academic students is that they often have difficulty following the logic of an explanation, or argument, particularly if the teacher presents an incomplete argument. Unlike more academically inclined students, these students do not perceive the relationships inherent in the material and so it becomes essential that these relationships are explicitly mentioned.

Included in the analytic scheme was the feature, "clarity, specificity and completeness of the concepts and relationships inherent in the material to be learned." To translate that feature to a clue, the investigator had to select criteria which would enable detection of instances where the teacher explicitly explained, or did not explain, the relationships in the material. Evidence was also needed that these relationships were being logically presented, i.e., whether the teacher could justifiably present the students with a certain conclusion based upon the previous information used. Toulmin's analysis of the steps involved in a logical argument presented a definitive work which could be applied readily when analysing lesson transcripts. Hence the particular form taken by Clue E.

In analysing the data for manifestations of Clue E, it became clear to the investigator that student contributions of components of Toulmin's argument pattern were striking in their logical appropriateness. It was decided, then, to take such contributions as an indicator of student "uptake" of the teaching. Analysis II, which follows immediately, is devoted to an examination of student contributions to complete arguments, as one indicator that the teaching had been successful.

Analysis II: Student Participation and Understanding

The preceding analysis has shown the development of the clue structure from the data and it is argued that the clues enable the reader to decide whether or not the teacher is exaggerating certain features of the teaching. However, to repeat Hirst's argument, the concept of teaching is strongly related to the concept of learning, the intention of all teaching activities being to bring about learning. There is a difference between being able to detect certain features of teaching and being able to claim that such strategies enhance the learning of the students. For such a claim to be made in this research study, evidence must be provided that the pedagogical strategies are, in fact, effective and that the students experience success. It has been proposed that the quality of instruction can be judged by looking at the amount of student participation and so portions of Lessons 2 and 3 have been analysed a second time in order to demonstrate the amount of student participation in the lessons. To achieve this, the analysis concentrates on the argument patterns being used by the students, such an analysis allowing for reflection upon the adequacy of student uptake of the "clues."

Student Participation Evident in Lesson Two

Three episodes from Lesson 2 are analysed below. The first and third were analysed for clues in Analysis I; they will therefore be familiar. (The clues are not repeated here.) Where appropriate, the presentation of the episodes is interrupted for commentary and analysis of the arguments being developed.

The setting for the **first episode** is preparation to discuss the results of three student experiments, in an effort to assess whether they can be explained satisfactorily by using the phlogiston theory. The "Phlogiston Argument," as it was dubbed earlier and presented diagrammatically in Figure 2, is an interpretation of burning in general in terms of phlogiston theory. In the first part of the episode, the teacher has the students review the Phlogiston Argument and, as well, both the "Theory Acceptance Argument" (Figure 3) and the "Theory Rejection Argument" (Figure 4), as these were called earlier.

T: First thing I want to ask you . . . can anybody tell me any parts of the phlogiston theory? How would he explain burning? (pause) Yes (S12)?	Teacher solicits Backing for Phlogiston Argument.
S12: The substance that leaves is called phlogiston?	S12 supplies part of Backing for Phlogiston Argument.
T: The substance that leaves is called phlogiston. Anything else . . . (S3)?	
S3: All things that burn have phlogiston in them.	S3 supplies more Backing.
T: All things that burn have phlogiston	

in them. (S6).

S6: When the fire goes out there's a concentration of phlogiston cutting off the air supply?

S6 completes Backing.

T: Right, good. That's another bit of information. That when something stops burning . . . how did you phrase that again . . . there's a concentration of phlogiston cutting off the air supply. Okay. So those were essentially what he believes happens during burning. All substances that burn have this element called phlogiston. It's given off during burning. When the air can't hold any more, then the thing stops burning. Now that's his theory. What you're doing is trying to see whether or not that's a good theory. And so my question is . . . how do you know as a scientist or just as . . . you know a normal everyday person on the street . . . how do you know whether or not a theory is a good one or not? How do we know whether we should accept this phlogiston theory of burning? (S9)?

Teacher summarizes Backing.

Teacher solicits Warrant for Theory Acceptance Argument.

S9: If it works on a numbers of experiments and tests. But I don't see how this could work on say a forest fire.

S9 supplies Warrant, then challenges Phlogiston Argument.

S3: Because of the air supply?

S3 explores challenge.

T: So you're saying that it would be considered to be a fairly good theory as to what happens during burning if . . . now just say that again . . .

S9: Well, if you have a candle burning and all of a sudden it goes out, and there's no more phlogiston left, then all the air . . . all the phlogiston's composed of the air . . . then how come in a forest fire . . . you know, just because it's a greater expanded area doesn't mean that there's more air . . . limitless. Do you understand what I mean?

S9 repeats "candle Data" but introduces "forest fire Data," then works through Warrant from Phlogiston Argument to hint at inconsistent Conclusion.

T: Yes.

S3: Can't put a beaker over though.

S3 proposes difference in the two situations.

S9: It's just hard to believe.

S3: You can't put a beaker over top of a

S3 clarifies the point.

forest fire though.

S9: I know . . . I don't know . . .
I just can't . . .

It is worth pausing to examine the students' contributions in the past few interchanges. S9's "forest fire Data" would be to the effect that "some fires don't go out by themselves like the candle flame did under the beaker," yet one of the Warrants in the Phlogiston Argument is that "phlogiston collects around a fire and smothers it." S9 is apparently referring to the great volume of air to be saturated with phlogiston, in the case of a forest fire (but it is still not "limitless"). S3 attempts to save the Phlogiston Argument by pointing out that there is no cover (beaker) over a forest fire—hence phlogiston could not easily saturate the surrounding air. As the first episode comes to a close, below, the teacher redirects the discussion to the main purpose of the lesson.

T: Yeah. When do you start doubting whether a theory is good or not?	Teacher solicits Warrant for Theory Rejection Argument again.
S9: When it fails.	
S2: If it doesn't work in all experiments?	S9/S2/S3 supply Warrant.
S3: You put it to work.	
T: Yeah. If you find that it doesn't really adequately explain your results, then you start thinking, well maybe this isn't such a good theory after all. So that was why I had you do three things yesterday. So we want to see what kind of results you got. And you tell me whether or not we could adequately explain them. Uh . . . the first one . . . the burning candle covered by a beaker. Okay we'll come back to that. Uh . . . the next two . . . you were supposed to weigh the small candle . . . burn it for ten minutes . . . that was too long . . . and then reweigh it. What I would like is I would like the data that you got from each group. Somewhere you should have put down how many grams it was before and after burning.	Teacher completes structure of Theory Rejection Argument with Data and Conclusion. Teacher reviews purpose of student experiments: to check adequace of the Phlogiston Argument.

And the same thing for the steel wool. You weighed it before and after burning. So what I'm going to do is I'm just going to call on each lab group and I'd like you to tell me what information you did get just so that we can have a look at them collectively. For the candle (S13) you were jotting it down again. Have you got the measurement for the candle before and after burning?

It is interesting to see how successfully several students provide pieces of the arguments developed in the first episode. As well, the interchange between S9 and S3 suggests an understanding of the subtleties involved in assessing the Phlogiston Argument. At the close of the episode the teacher has students review their experimental results from the day before, in anticipation of what follows next.

The **second episode** follows almost immediately upon the first. Students are to explain two sets of experimental results according to phlogiston theory: the burning candle covered with a beaker, and the candle weighed before and after it burns. The transcription begins with students summarizing the results of the first experiment. (This portion of Lesson 2 was not analysed in Analysis I.)

T: It burned out after a while. Okay, so when you light the candle and cover by a beaker, the flame gets dimmer and it eventually goes out. If you were explaining those results using the phlogiston theory, how would you explain that? (S12)?	Teacher summarizes Data, and then solicits Backing to support Warrant for a phlogiston interpretation.
S12: All the phlogiston . . .	Students use Warrant.
S3: . . . left the candle . . .	
S12: . . . left the candle and it used up all the air.	Warrant.
T: Okay, all the phlogiston left the candle and used up all the air. Okay. So, anything else you'd like to add to that? So does that sound like an acceptable explanation?	Teacher invites students to judge the interpretation.

Students have provided a straightforward interpretation of the results of their first experiment according to the following argument (Figure 8). The teacher's question about acceptability relies on the Theory Acceptance Argument developed earlier (refer to Figure 3). The discussion continues below.

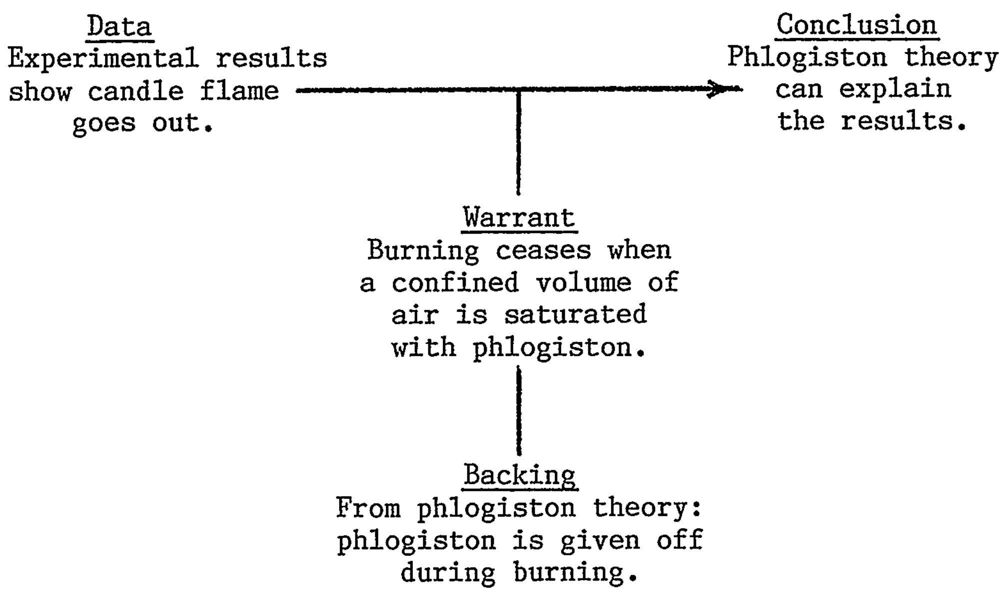

Figure 8. Phlogiston Interpretation of the "Burning Candle Covered by a Beaker" Experiment

T: (S6) what were you going to add to that?

S6: I was just going to say that the amount before burning . . . and the amount after burning would be the amount of phlogiston that left.

S6 uses Backing to support Warrant for candle being lighter.

T: Okay, so another thing that you could perhaps say is the difference between the two measurements could be explained . . . that would be the amount of phlogiston. Right. Let's go on to the second one then. Uh . . . the candle. The candle is weighed, burned for five to ten minutes, weighed again. What do

Second experiment discussion begins.

Teacher solicits

you notice about the measurements before and after? (S5).	Data.
S5: They weigh more before they get burned, and then after they got burned they weighed less.	S5 provides Data.
T: Okay. That's the observation (S10). The observation is . . . we're on number 2 now . . . it says record the observations and explain the results. So the observations were that it weighs less afterwards than it did at the beginning. How would you explain that . . . the fact that it does weigh less after . . . (S11)?	Teacher repeats Data, and asks students for an explanation.
S11: Pardon?	
T: Explain why the candle would weigh less after burning than before burning.	
S11: Because you're burning it away.	S11 misses the point.
T: In terms of phlogiston. You see we're trying to see if the phlogiston theory is acceptable.	Teacher reminds S11 to use phlogiston theory.
S11: Well all that stuff's leaving the candle.	S11 uses Backing.
T: Okay, so all the phlogiston is leaving the candle. So why would it weigh less at the end?	Teacher solicits Warrant.
S11: Because it's leaving.	S11 provides Warrant.
T: That's right, it's not there at the end. Anything else, (S5) that you want to add to that?	
S5: No, that'll do.	
T: Yeah, that's fine. It still seems to be working. Does this theory adequately explain the results? Well, yes, it explained the candle going out when it was covered by a beaker. It explained why it got less after burning. We've got one set to put on at the end . . . these are the steel wool ones. Okay, (S9) and (S12), have you got the data for the steel wool?	Teacher stresses Conclusion and invites students to judge it.

The results of the second experiment are, once again, interpreted successfully by phlogiston theory. Student contributions suggest an entirely satisfactory capability to stay within the confines of the Phlogiston Argument, in fashioning the interpretation (refer to Figure 9), and their judgement of the interpretation follows the Theory Acceptance Argument (Figure 3).

Data
Experimental results show a decrease in mass. ⟶ Conclusion
Phlogiston theory can explain results.

Warrant
Whenever phlogiston departs from burning substances the residue weighs less.

Backing
From phlogiston theory: phlogiston is given off during burning.

Figure 9. Phlogiston Interpretation of the "Candle Weight Before and After Burning" Experiment

As the discussion continues in the **third episode,** however, the phlogiston theory is judged to be less than satisfactory for interpreting the final set of results concerning the burning of steel wool. (This portion of transcription was examined in Analysis I, and indeed the two arguments which are developed in the third episode have been presented already as Figure 5 and Figure 6.) The lesson resumes.

T: (writes) Okay, so now looking at the third one then . . . the steel wool is weighed, burned, then weighed again. You	Teacher solicits summary of results (Data).

have to record your observations . . .
(S7), how would you sum up the observations from all the different groups?

S7: The steel wool is getting heavier.

S7 supplies Data.

T: Yeah, the steel wool is getting heavier as it burns. So those are the observations. Now you've got to try and explain those results using the phlogiston theory.

Teacher asks students to use Backing to test Warrant (steel wool should decrease in mass).

S3: Phlogiston from the burning matches is attaching to the steel wool.

S3/S9 use Backing to explain the Data, but this contradicts the Warrant. (Students have had to resort to an "extra" supply of phlogiston.)

T: The phlogiston from the burning match is attaching to the steel wool.

S9: Causing a build-up on the steel wool.

T: Causing a build-up on the steel wool . . . of phlogiston?

S9: Yeah.

T: Okay. Anything else you'd like to offer as a way of explanation?
'Makes sense? Yes?

"Okay" means "could be."

Teacher waits for reaction.

S6: If there's a build-up on the steel wool of phlogiston . . . and the phlogiston is supposed to burn . . . then how come you couldn't light it again?

S6 questions the soundness of the "extra" supply of phlogiston.

T: Very good point.

S9: (inaudible)

T: That's a possible explanation.

S2: What did she say?

T: (S3) said that the phlogiston builds up on the steel wool . . . and that's why it gains weight. (S6) pointed out that phlogiston is supposed to burn . . . and yet you kept putting the matches to it, and eventually, it stopped burning. That was when you were supposed to stop.

S3: But if you keep putting the match to it, you're still putting on phlogiston.

S3 tries to salvage the "extra" supply of phlogistion.

T: And then (S9) offered the possible explanation that maybe once it's burned once,

S9 adds another ad hoc possibility.

it won't burn a second time. Yeah.

S8: But with the candle, it would still burn a second time.	S8 is dubious.
T: That's true. Yes (S6)?	
S6: That wasn't explained in the theory was it?	S6 states Conclusion: phlogiston theory isn't working in this case.
T: Sorry?	
S6: That wasn't explained in the theory.	
T: It wasn't explained in the theory, no.	
S6: So . . . that's not really . . .	S6 starts Conclusion for Theory Rejection Argument.
T: Whenever you get . . . yes (S9)?	
S9: Maybe only the wool holds phlogiston . . . and after the phlogiston in the wool is burned off, . . . the steel wool won't light fire.	S9 offers a last ad hoc possiblity.
T: Yeah, you've got another possible explanation. Whenever you get to a point like this, where it gets harder and harder to come up with an explanation that seems to fit . . . then you start asking yourself whether or not this theory is perfectly acceptable. Good. I like your ideas.	Teacher summarizes Theory Rejection Argument, stressing the need for more and more ad hoc inventions to "save" the theory.

Three arguments, all presented earlier in diagrammatic form (in Analysis I), are pertinent to the interpretation of this episode. The Theory Rejection Argument, presented in general terms as Figure 4, is laid out diagrammatically for this specific argument about the "steel wool burning experiment" in Figure 6. As well, Figure 5 shows the structure of the argument which concludes with a judgement of inadequacy about the phlogiston theory in this case. Especially interesting in this episode is the persistence of students S3 and S9 in supplying ad hoc inventions to "save" the phlogiston theory, countered by the skepticism of S6 and S8. S9 apparently has had a change of heart since the first episode, earlier in this same lesson: there S9 introduced the inconsistent "forest fire data." S3's role was the same in the first and third episodes, however, and S6 and S8 do not emerge as skeptics until the third episode. Generally speaking, the collective construction of a rejection argument for phlogiston theory, in the third episode, shows intense involvement by at least some of the students--notably those four.

Student Participation Evident in Lesson Three

In Lesson 3 the discussion centres mainly on the oxygen theory and its ability to explain the experimental results. The preparation for this work follows a pattern similar to that used in Lesson 2: the burning process in general is interpreted in terms of the oxygen theory before the "Theory Acceptance Argument" (Figure 3), the "Theory Rejection Argument" (Figure 4), and the "Theory Comparison Argument" (Figure 7) are reviewed. This portion of transcript, which follows immediately, was previously analysed in Analysis I.

T: On the board now, what I've written is the oxygen theory of burning. "All burning substances combine with oxygen. When there's no more oxygen, or for that matter no more substance, the burning process would stop." Now that's his explanation for what he thinks happens during burning. Today which do you think is more acceptable . . . or which do you think we do tend to accept? Do we accept the phlogiston theory of burning?	Teacher summarizes parts of the oxygen theory, then solicits Conclusion to the Theory Comparison Argument.
S's: Oxygen (together).	Students offer a Conclusion.
T: Or the oxygen.	
S's: Oxygen.	
T: Yeah, the oxygen theory. Have you any	Teacher solicits

idea why we think that that's more acceptable than the phlogiston one?	Warrant for the Theory Comparison Argument. S2 has difficulty articulating the Warrant.
S2: Because experiments prove that . . . uh, when there's no more oxygen the process stops.	
T: So in other words, you could explain the burning process if you said that. Is that what . . . yeah. That one, substances do combine with oxygen . . . and then when there's no more oxygen the burning process stops. Okay, 'cause remember last time . . . uh, (S9), I think you explained it . . . what makes a good theory? Why do we say that something's a good theory or a bad theory?	Teacher elaborates upon S2's response concerning the oxygen theory, then solicits Warrant for the Theory Acceptance Argument.
S9: Well, you have to prove it with experiments . . . like it could have phlogiston and no oxygen and it would still not burn.	S9 suggests Warrant for the Theory Acceptance Argument.
T: Okay. Yeah, what we were trying to do last time . . . we came up with a problem and you were giving me the explanation of these three sets of results last time. Uh, phlogiston theory explained this set of results quite well (points to "candle covered by a beaker"), it explained that set of results quite well (points to "candle burning") . . . but for the third one, that's where we ran into the problems. That's where we started to think that maybe it wasn't perfectly acceptable. Because, although you gave me some really good ideas about why the steel wool would weigh more after burning, it	Teacher judges the phlogiston theory by the Theory Rejection Argument.
tended to get more and more complicated. So today, the reason we think that the oxygen theory is more acceptable is that it seems to explain the results a little bit more clearly.	The teacher provides the Warrant and Conclusion to the Theory Comparison Argument.

It is interesting to note that when S3 has difficulty articulating the Warrant for the "Theory Comparison Argument," the teacher tries to help by asking the students to recall the Warrant for the "Theory Acceptance Argument." The teacher apparently realizes that it would have been easier for the students to understand what was required if these two arguments had been discussed in the reverse order and so an effort is made to clarify the situation. As the lesson continues below, the teacher re-establishes the continuity of the work by asking the students to interpret the experimental results using the oxygen theory. (In this way the students are being asked to establish the Data for the "Theory Comparison Argument.")

T: So, let's just go back and try and explain the three sets of results using this oxygen theory of burning. The data that we got last time . . . I think it was (S1) who pointed it out . . . said that the flame got dimmer and then went out. If you had to explain to somebody . . . using the oxygen theory . . . why the flame gets dimmer and goes out . . . what would you say (S2)?	Teacher asks students to establish Data for Theory Comparison Argument.
S2: Because you're losing oxygen and it's leaving the air. When there's no more oxygen, it goes out.	S2 offers an interpretation of the results.

S2 has offered a satisfactory interpretation of the results according to the argument represented in Figure 10.

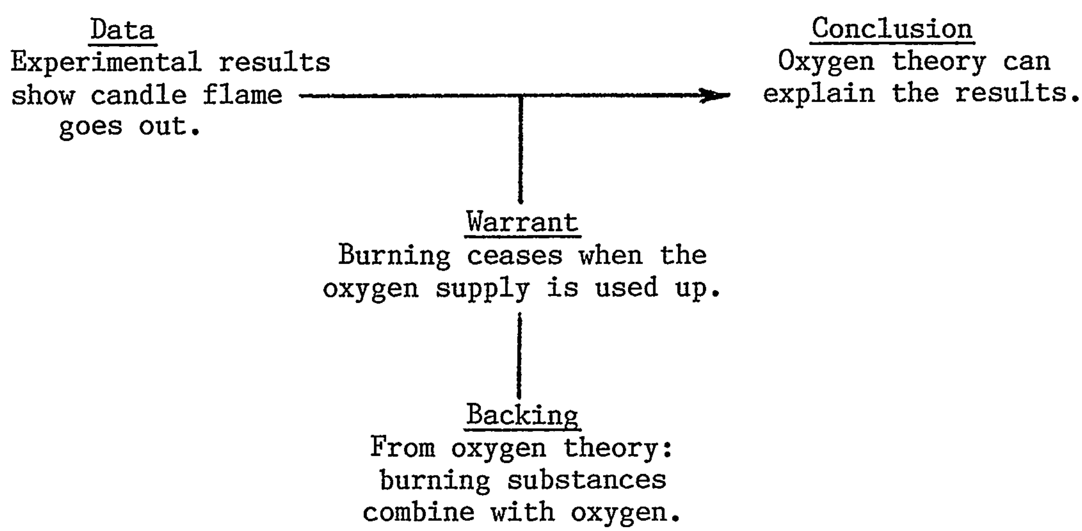

Figure 10. Oxygen Interpretation of the "Burning Candle Covered by a Beaker" Experiment

This explanation will be further elaborated upon by S2 a little later in the lesson. The discussion continues.

T: Right. That would be fine. Uh, number two . . . the candle burning . . . the candle weighed less after five minutes of burning. If you wanted to explain to somebody why the candle weighed less after it had been burning for five minutes, what would you give in the way of an explanation? (S3)?	Teacher repeats Data for second experiment, then asks for an interpretation of results.
S3: Uh, the oxygen combined with the material and it was burnt off by the candle flame.	S3 offers an interpretation of the results.
T: And it was burnt off by the candle flame?	
S3: And then it escaped away.	
T: Uh, yes good. The oxygen combined with the candle and the substances were given off because what form were they in . . . solid, liquid or gas?	
S3: Gas.	
T: Yes, because a lot of gases were produced and they escaped into the air . . . and so they weren't weighed. Yes, good.	

The explanation given by S3 indicates a clear understanding of the concepts involved and the argument used is shown in Figure 11.

Data
Experimental results show a decrease in mass.

Conclusion
Oxygen theory can explain results.

Warrant
Whenever products of burning are gaseous they might escape from an open system without being weighed.

Backing
From oxygen theory: burning substances combine with oxygen. If burning occurs in a sealed container there is no change in the total mass.

Figure 11. Oxygen Interpretation of the "Candle Weight Before and After Burning" Experiment

The third set of experimental results are then interpreted.

T: The third one . . . if you had to explain, using the oxygen theory, why the steel wool weighs more after you burn it, how would you explain that using the oxygen theory? (pause)	Teacher solicits interpretation of steel wool experiment using the oxygen theory.
S17: 'Cause the steel wool held in the oxygen when it burned?	S17 offers an an interpretation.
T: Yeah, it combines with the oxygen as it burns.	
S17: That's the molecules.	

At this stage the explanation given by S17 is in very rudimentary form but it becomes easier to judge the depth of understanding when S17 expands the answer a short time later. This is evident in the discussion which follows, in which S2, S3 and S17 are asked to repeat their answers.

T: Right, good. Uh, if you think you can remember this information, don't bother writing it down. But what I would recommend is if you would like to just jot it down . . . just the writing that's in blue . . . I would just put it on the back of the summary sheet that you've got in front of you at the moment. So maybe just on the back so that you remember the difference between them . . . just the writing in blue would sum up what we really need. Okay, (S2) I have to go back to you again. Tell me again what you said for your explanation.	Teacher solicits repeat of explanations previously offered by S2, S3 and S17.
S2: Uhmm, as it burns . . . when it's covered it starts losing the oxygen and then it starts to go dimmer, . . . and then it loses all the oxygen.	S2 reiterates the explanation.
T: Uh, what do you mean when you say it loses all the oxygen?	
S2: The oxygen . . . (laughs)	
T: No, keep thinking it through.	
S2: Okay, when you put the beaker over the candle, uhmm, you're not getting any more oxygen so its getting . . . I don't know . . . so there's less and less oxygen and then finally it's absorbed all the oxygen so you have none left.	S2 refines the explanation.
T: Right, good . . . that's fine. Okay, uhmm . . . so (writes) when the beaker covers the candle . . . uhmm, it limits the amount of oxygen . . . uh, more and more of it is used up? And how should I finish that off?	
S2: Uhmm, and then when there's no more oxygen left, the candle went out.	Explanation completed.
T: Right. (writes) When the beaker covers the candle, it limits the amount of oxygen, more and more oxygen is used up and when there's no more left, the candle goes out. Right, thanks (S2). (pause) Uh, (S3), it	

was you who I asked before. Can you give me the explanation for why the candle weighed less after burning?	Teacher solicits repeat of S3's response.
S3: Uhmm, when the candle was burned the molecules turned into gas and mixed with the oxygen molecules and they floated away.	S3 refines explanation.
T: Right, good. I'll get that down exactly as you said that. (writes) Did you say when the candle burns the . . .	
S3: Molecules . . .	
T: Molecules turn into a gas . . . combine with the oxygen . . . and float away?	
S3: Yeah.	
T: (writes) And the last one (S17).	Teacher solicits repeat of S17's explanation.
S17: As the steel wool burns it attract . . . it held in . . . the more the oxygen got into it and it held it. So it collected the oxygen.	S17 refines explanation.
T: (writes) Was attracted into the steel wool?	
S17: Uhmm uhmm.	
T: Good, thank you. Good so we've got two completely different theories of burning . . . the phlogiston theory and the oxygen theory. And this is the one that seems to be more acceptable because it seems that it can explain the results with less difficulty than the phlogiston theory.	Summary of the Theory Comparison Argument.

In the above transcription an interesting feature is the way in which the three students S2, S3 and S7 refine their explanations when they are asked to repeat them in order for the information to be written on the blackboard. The responses of the three students became noticeably more "sophisticated" at this point compared to their original statements and it appears that the students feel confident in their understanding of the work and are willing to express their knowledge clearly and succinctly. It is interesting to speculate whether the refinements expressed first by S2 encouraged the other two students to do the same thing. S17 has now shown a clear understanding of the argument represented by Figure 12.

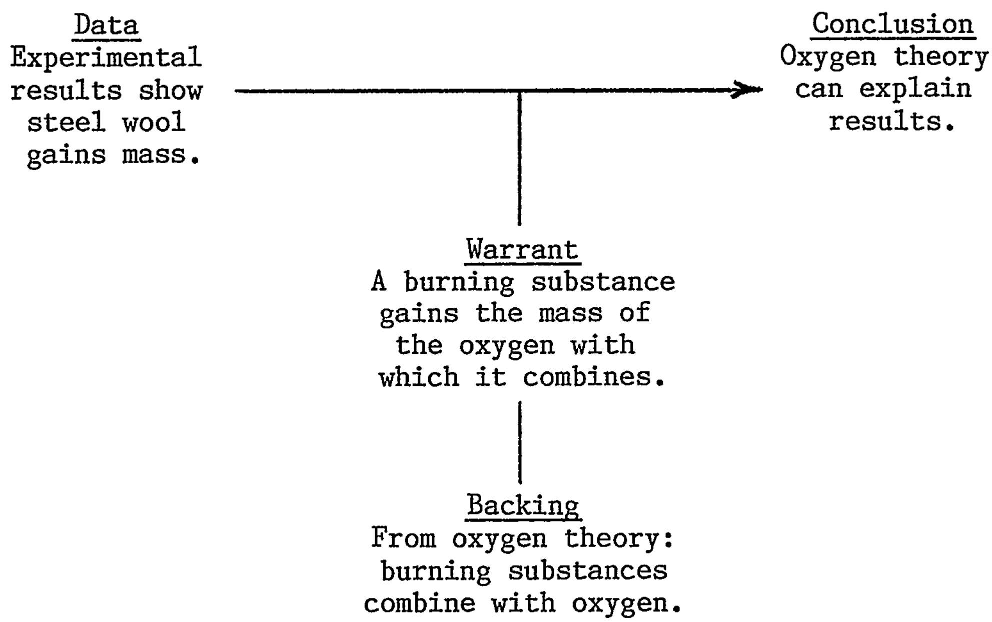

Figure 12. Oxygen Interpretation of the "Steel Wool Burning" Experiment

Analysis II was done for the purpose of reflecting upon the effectiveness of the pedagogical strategies being used. The examination of student contributions to complete arguments was used as an indicator of student "uptake" of the teaching, and it is argued that this analysis has provided evidence that the students were indeed successful in making significant, logical contributions and that the teaching was producing the desired effect.

Summary

Chapter Three provided a theoretical perspective on teaching that is consistent with the learning needs of non-academic students. The research methodology required that this theoretical perspective be translated to the context of science education. In this study the step involved translating the theoretical perspective to the context of the non-academic science classroom through the development of a clue structure and this was the task in Chapter Four. The clue structure makes the identified theoretical perspective applicable to the phenomenon to be studied (in this case, the quality of classroom interactions) and moves the research from the realm of the theoretical to that of the practical. The research methodology has been designed to detect systematically certain pedagogical features and it is the clue structure which makes possible this detection by producing a systematic examination of the practical events.

To derive the clue structure, use was made of the analytic scheme that was developed and presented in the previous chapter. This analytic scheme consisted of theoretically formulated pedagogical features which, if emphasized or exaggerated, have the potential to enhance the learning outcomes of non-academic students. It was used in the data analysis, acting like a "set of lenses" through which to view the data, determining what was looked for. As the lesson transcriptions were examined the investigator derived criteria (clues) for detecting instances of an emphasis on these pertinent pedagogical features.

Seven clues were derived, each one related empirically to a specific teaching strategy exemplifying an emphasis on one of the categories of the analytic scheme. Analysis I described the development of the clue structure from the original analytic scheme and showed that an emphasis on the specific teaching features can be detected using the following clues.

CLUE A. Provision of an overall perspective of the work to be covered and the objectives involved (verbal and/or written).

CLUE B. An emphasis on the significance/function of the individual parts of the instructional sequence (verbal and/or written).

CLUE C. Summary of the key concepts by the teacher and/or students in a verbal and/or written manner.

CLUE D. Use of a variety of cues to help the student understand the steps that are to be followed.

CLUE E. Provision of the data, warrant and conclusion to arguments.

CLUE F. Definition of new terms before use.

CLUE G. An emphasis on how pieces of information fit together by linking previous work to new work related to it.

This was followed by a review of the theoretical background from which the analytic scheme and the clues were derived, providing further explanation of the clues and emphasizing the correspondence between the clues and the analytic scheme.

The development of the clue structure resulted in a systematic examination of the practical events and thus partially fulfilled the aim of the research. However, it was felt that this detection of certain features of teaching left the research incomplete without accompanying evidence that the teaching was effective in helping the students learn. In other words, the clues were all pedagogical moves but no attention had yet been paid to the learning that might, or might not, be taking place. Hirst's characterization of teaching, pointing out that the intention of all teaching activities is to bring about learning, was used to argue that there is a difference between being able to detect certain features of teaching and being able to claim that such strategies enhance the learning of the students.

It was proposed that the quality of instruction can be judged by looking at the amount of student participation and so portions of Lessons 2 and 3 were analysed a second time in order to demonstrate the amount of student participation in the lessons. This comprised Analysis II, devoted to an examination of student contributions to complete arguments, as it was decided that such contributions reflected student "uptake" of the teaching, providing one indication that the teaching had been successful. This analysis provided evidence that the students were indeed successful in making significant, logical contributions and it was concluded that, according to this indicator, the teaching had been successful. The remaining aim of the research was thus fulfilled.

Chapter 5

CONCLUSIONS, LIMITATIONS AND IMPLICATIONS

This final chapter reviews the argument and methodology of the study before presenting the conclusions reached as a result of it. The limitations of the study are brought to the reader's attention and then suggestions are made regarding possible implications of this work for further research and for practice.

Review of the Argument and Analysis Presented in the Study

The study began with the investigator's contention, consistent with evidence reported by Goodlad, Bloom, and others, that non-academic students may be receiving a poorer quality of instruction than academic students. Evidence in the literature also suggested that few variations in teaching strategies are being used for non-academic students, even though it has been proposed that one way to cater to individual differences in school learning is to alter instructional methods. As a practitioner, the investigator rejects the widely held belief that non-academic students are "destined" to have little academic success in school, believing rather that academic achievement can be improved if the students are provided with favorable learning conditions. For purposes of this study, the phrase "favorable learning conditions" was the important one because the investigator supported the position that in order to effectively adapt instruction to suit the needs of non-academic students one must have a clear conceptualization of school learning.

A review of relevant empirical studies was disappointing. "Mastery learning" studies have produced various and somewhat inconsistent conclusions about the effectiveness of this type of instruction to improve achievement. Indeed, in a very recent article by Slavin (1987), the author examined recent literature on achievement effects of practical applications of group-based mastery learning in elementary and secondary schools over periods of at least four weeks. Slavin used a review technique, "best-evidence synthesis," which combines features of meta-analytic and traditional narrative reviews, and this review found essentially no evidence to support the effectiveness of group-based mastery learning on standardized achievement measures. It was also noted that although effects were generally positive on experimenter-made measures, these effects were only moderate in magnitude and there was little evidence that the effects were maintained over time. "Aptitude-treatment interaction" studies offered a reductionist approach to identifying instructional modes that best suit the learning needs of the students--and a reductionist approach is not very helpful to a classroom teacher. Finally, "classroom management" studies made little attempt to differentiate between managerial and instructional variables when they were correlated with student participation.

In contrast, the approach taken in this study establishes epistemological connections between attributes of teaching as determined theoretically (in an "analytic scheme") and their defining characteristics in classroom practice (a "clue structure"). The clues thus provide a means to answer the question, "How do I know it when I see it?", while the categories of the analytic scheme guide one toward the "it's" to be looked for in the first place. This approach constitutes an effort to contribute to knowledge about the phenomena associated with teaching science to non-academic students, while at the same time providing a contribution more applicable to informing practice than the studies reviewed. The backbone of the argument is a conceptual connection between learning and teaching: the deceptively simple point that in order to teach something one must appreciate what is required to learn it. Thus the theoretical work guiding development of the analytic scheme had to be concerned with teaching as it relates to the learning needs of non-academic students.

The investigator began a systematic conceptualization of the teaching which non-academic students need in order to learn and the first step was to consider Hirst's classic treatment of the concept of teaching. It was contended that the features of teaching mentioned by Hirst are the same for both academic and non-academic students but that these features need to be exaggerated for non-academic students. Consequently, use was made of Bloom's definition of "cues" to provide an insight into <u>how</u> such exaggerations might be made, while Carroll's work regarding "quality of instruction" and "ability to understand instruction" provided clarification of <u>what</u> features of teaching might be emphasized. From this conceptualization the investigator categorized certain pertinent teaching features which, if emphasized, have the potential to enhance the learning of non-academic students. These features constituted the analytic scheme and they were categorized in the following way:

Indicative features of teaching

1. Instruction as to what is to be learned.

2. Directions as to what the learner is to do in the learning process.

Meeting the present learning state of the students

3. Clarity, specificity and completeness of the concepts and relationships inherent in the material to be learned.

4. Teacher language which is within the grasp of the learner.

5. Adequate preparation for each step of the learning.

This theoretical perspective was translated to the context of the non-academic science classroom through the development of a clue structure, a set of empirically formulated clues for identifying practical instances of the events. In this way the research moved from the realm of the theoretical to that of the practical and it resulted in a systematic examination of the practical events. In Chapter Four the reader was shown how each of the clues emerged from the data when the analytic scheme was used to guide the analysis, and the resulting clue structure was composed.

The clue structure consists of the following seven clues:

A. Provision of an overall perspective of the work to be covered and the objectives involved (verbal and/or written).

B. An emphasis on the significance/function of the individual parts of the instructional sequence (verbal and/or written).

C. Summary of the key concepts by the teacher and/or students in a verbal and/or written manner.

D. Use of a variety of cues to help the student understand the steps that are to be followed.
   Examples: a) repetition of instructions.
   b) use of both verbal and written instructions.
   c) description and demonstration of the steps to be followed.

E. Provision of the data, warrant and conclusion to arguments.

F. Definition of new terms before use.

G. An emphasis on how pieces of information fit together by linking previous work to new work related to it.

It was argued that each clue, a specific teaching strategy, exemplified an emphasis on one of the theoretically determined features in the analytic scheme. However it was felt that in addition to detecting certain features of teaching, the researcher should provide evidence that the students were in fact experiencing success in learning. For this reason, portions of the data were analysed a second time in order to demonstrate the amount of student participation in the lessons. This analysis concentrated on the argument patterns being used by the students and there was evidence that the students were successful.

Conclusions

The investigator found that as a result of conceptualizing teaching that is consistent with the learning needs of non-academic students it became possible to suggest that certain features of teaching, if emphasized, might improve academic achievement for these students. When the investigator analysed the lesson transcriptions using the analytic scheme it became possible to detect features of teaching which, through their presence, exemplify an exaggeration of the categories within the analytic scheme. As the investigator was also the teacher involved it was a revelation to suddenly be able to detect systematically the specific strategies being used to help the students understand the instruction. It had been the teacher's firm resolve to alter the instruction so that it was better suited to the "learning state" of the students, but until the data were analysed and the clue structure emerged the teacher was intuitively making changes but was unaware of specific modifications being made. The investigator therefore concludes that the clues are consistent with the conceptualization presented in Chapter 3 and that they do enable one to detect an emphasis, or lack of it, on certain features of teaching. Furthermore, the analytic scheme and accompanying clue structure seem to be appropriate for use in studying the <u>qualilty</u> of classroom interactions, specifically the intellectual climate within the classroom.

Limitations of the Study

A limitation of the study is that it has been a self-report. As mentioned in Chapter One, the investigator accepted the premise proposed by Roberts (1984) that in order to conceptualize what causes events to happen (in this case, what causes students to learn better), one must consider both the technical and the intentional components of practical causation. The investigator therefore decided that a holistic or contextualist study of the phenomenon would allow for a complete conceptualization of the quality of classroom interaction because only such a study allows for consideration of both the technical and the intentional components of practical causation.

This study has presented the technical components of practical causation in this specific science classroom, identifying pedagogical strategies being used throughout the lessons. However, because the investigator was also the teacher involved in the study, the intentions of the teacher have not been brought to the attention of the reader. The intentional aspect of practical causation may therefore appear to have been disregarded, but this was a crucial part of the teacher's approach to the lessons. The teacher had firmly resolved to try to enhance the students' achievement by using as many teaching techniques as possible.

If the investigator had been transcribing and analysing another teacher's classes, the data would also have included a discussion with the teacher about the intentional aspects of the classroom teaching.

Implications for Further Research

This study has been an attempt to systematically analyse the quality of teaching in a non-academic science classroom. The analysis has concentrated on the intellectual aspects of the teacher-student interactions, seeking to identify pedagogical strategies that might enhance learning. Such work has implications for further research and several research questions arise from the study. 1. Can this analysis be used effectively in non-academic classrooms in other subject areas such as English, Mathematics, etcetera? Does the nature of the material being presented in other subjects render these clues ineffective or are they equally useful for analysis in different subject areas? 2. Will the analysis be effective with other teachers? In other words, are the clues "powerful" enough to be used by other teachers? The clue structure was successful in this particular study but this might change when other teachers are involved. 3. If teachers do find it possible to analyse their lessons in this manner, is it possible for them to reflect upon their actions and subsequently change their strategies? Practising teachers may find it possible to analyse their lessons but will they make use of the information gained? It would be interesting to study the amount of reflectiveness that normally follows such an analysis and to study whether subsequent changes in teaching strategies occur. 4. What about the role of teacher intentions? Could it be that teachers of non-academic students give up on them and, through many subtle clues, communicate that they are just putting in time? If this is the case, research could show the type of results obtained when the pertinent strategies were used, but the teacher intention was weak. The investigator reiterates the argument that it is not enough to consider only the technical component of practical causation, which is what the clue structure represents, because the intentional component is an equally important factor. The teacher's determination to succeed must also be considered.

Implications for Practice

Involvement in this study has made the investigator much more aware of the intellectual aspects of not only the non-academic science classroom but of all types of science classrooms. As the conceptualization of the learning needs of non-academic students developed, so it became apparent how to alter teaching techniques in order to better meet these needs. The increased awareness of possible difficulties facing these students as they attempt to understand instruction made it possible for the investigator to try to reduce these difficulties.

The use of the clue structure has shown that it is possible to detect pedagogical strategies used throughout a lesson and consequently to form an opinion about the "intellectual climate" of the classroom. This could find a use in helping experienced teachers become more reflective about their practice. Teachers often reflect on their work and make judgements concerning the presentation of a course--the appropriateness of the order in which the material is presented, the level of difficulty involved for the students, the amount of practice being provided, etcetera. Sometimes teachers have difficulty analysing the cause of a problem that has arisen during a particular section of work and consequently remedies are difficult to find. This is often particularly true for teachers dealing with non-academic students and so it is envisaged that a study such as this one could provide a useful technique for helping teachers reflect on the teaching techniques they use at present.

In a similar way this study could provide student teachers with a method for analysing and reflecting upon their actions. It is often a daunting experience for student teachers when they are faced with a class of non-academic students for the first time. Their lack of experience makes it difficult for them to decide how best to achieve success with these students and they may have little knowledge of criteria to use when judging their own teaching performance. This study could perhaps provide one possible method for carrying out such reflection.

Within Alberta, the recent revisions being made to the Senior High Science Curriculum include the formation of more General Science courses. At the same time, the proposal has been made that a student must obtain credits in a minimum of two science courses in order to obtain a General High School Diploma. These two factors will, in the investigator's opinion, result in a larger number of non-academic science classes in the future and under such circumstances it is likely that a greater number of teachers will be involved in teaching these classes.

Some teachers may have no previous experience with classes of non-academic students, or may not have taught such classes for several years. It is therefore envisaged that the work carried out in this study could be used for In-service programmes, to better inform the practice of teachers.

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APPENDIX

(Lesson 1)

TOPICS TO BE COVERED

An historical view of the burning process

How easily do different substances burn

The conditions needed for the burning process to occur

The substances produced as a result of burning

Different techniques for extinguishing fires

Injuries and deaths resulting from fires

Common causes of explosions

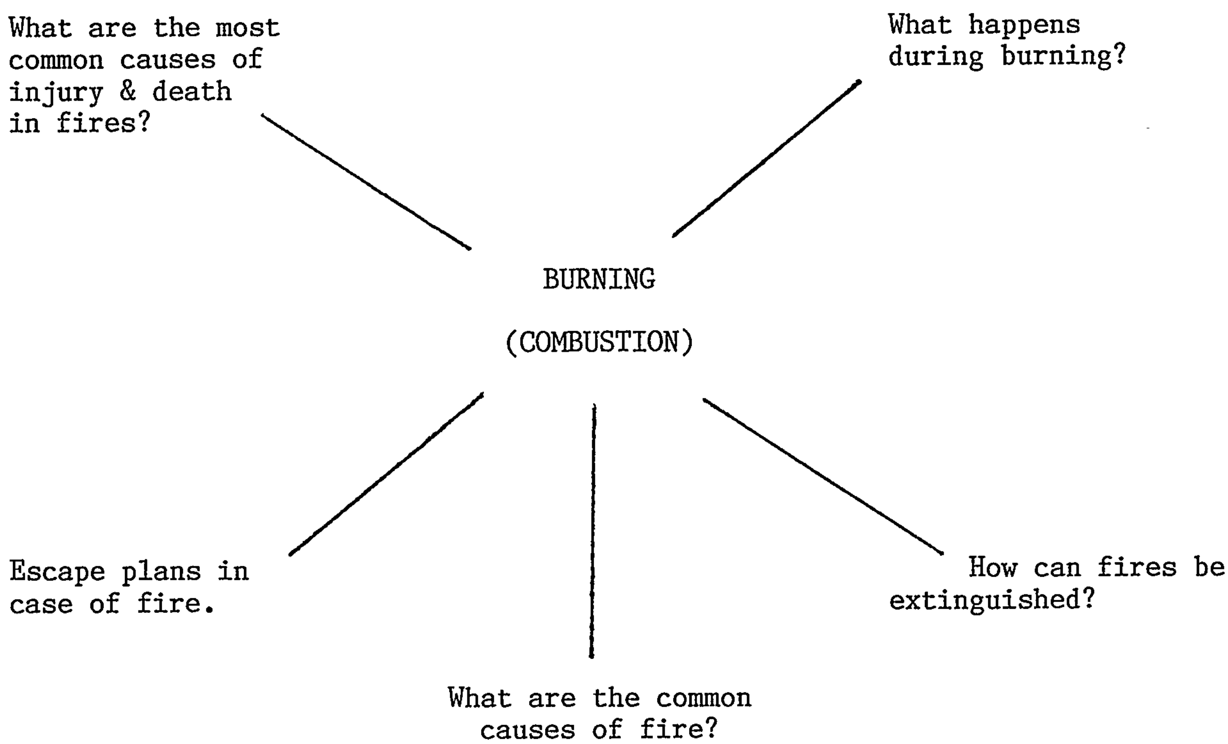
Recognizing potentially hazardous situations for fires and explosions

Planning escape routes in case of fire

Making flammable materials fire resistant

(Lesson 1)

FACTS ABOUT BURNING (COMBUSTION)



(Lesson 1)

ACTIVITY 2: WHATEVER HAPPENED TO PHLOGISTON?

Purpose - To know the different explanations offered by different scientists for the burning process.

2-1. Did something seem to enter or leave the match as it burned? Explain your answer.

2-2. According to Stahl's phlogiston theory, is phlogiston in
a.) wood, paper and coal?
b.) the wood ashes left after a fire?
c.) glass or stones?

2-3. According to the phlogiston theory, everything that burns contains the same element. True or false?

2-4. What finally happens to the burning candle? Use the phlogiston theory to explain what you observed.

2-5. What was the total weight of the candle and the pad before the candle was lighted (Step C)?

2-6. After the candle was lighted (Steps D and E), was the total weight of the candle and pad more, the same, or less than before the candle was lighted? Use the phlogiston theory to explain

2-7. What was the total weight of the steel wool and the pad before the steel wool was lighted?

2-8. When the steel wool stopped burning and cooled, what was the total weight of the steel wool and pad?

2-9. After the steel wool was lighted, did it weigh <u>more</u>, the <u>same</u>, or <u>less</u> that before it was lighted?

2-10. According to Lavoisier, what element combines with burning substances?

2-11. According to Lavoisier, why does it sometimes appear that something is lost when things burn?

2-12. When steel wool burns, it gains weight. Use Lavoisier's theory of burning to explain the weight gain.

2-13. Describe how Lavoisier's experiments helped to disprove the phlogiston theory.

2-14. Describe how the Law of Conservation of Mass applies to burning.

BLACKBOARD WORK FOR LESSON ONE

Activity 2: Whatever happened to phlogiston?

Purpose - To know the different explanations offered by different scientists for the burning process.

To be done:

(1) Candle under beaker

- record observations
- explain, using the phlogiston theory

(2) Candle weighed, burned, reweighed

- record observations
- explain, using the phlogiston theory

(3) Steel wool weighed, burned, reweighed

- record observations
- explain, using the phlogiston theory

BLACKBOARD WORK FOR LESSON TWO

Purpose - To know the different explanations offered by different scientists for the burning process.

Experimental Results

Observations

Candle - Mass before burning

- Mass after burning

Steel Wool - Mass before burning

- Mass after burning

	Candle under beaker	Candle weighed, burned, reweighed	Steel Wool weighed, burned, reweighed
Observations			
Explanations			

(Lesson 2)

SUMMARY SHEET - ACTIVITY 2

1. How did George Stahl explain the process of burning?

2. a.) Why did Lavoisier think that the 'phlogiston theory' was incorrect?

   b.) What was Lavoisier's explanation for the burning process?

3. How can one demonstrate that the Law of Conservation of Mass applies to burning?

BLACKBOARD WORK FOR LESSON THREE

Lavoisier's Oxygen Theory of Burning

All burning substances combine with oxygen. When there is no more oxygen (or no more substance) the burning process stops.

Explanation of Results

(1) Candle covered by a beaker

- the flame went dim and then went out.

Explanation

(2) Candle burning

- the candle weighed less after burning for five minutes.

Explanation

(3) Steel Wool burning

- weighed more after burning.

Explanation