DEVELOPING A METHODOLOGY FOR ANALYSING AND EVALUATING TEACHING STRATEGIES IN UNIVERSITY SCIENCE TEACHING: AN EXPLORATORY STUDY

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF EDUCATION

in the Department

of

Education

We accept this thesis as conforming to

the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

January, 1971

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Abstract

Purpose of the study

The study explored an approach to analysing and evaluating strategies for teaching science concepts at the first-year university level based on B.O. Smith and co-workers conceptual framework of teaching. As such, the study represents an attempt to bridge the gap between a recently developed theoretical view of teaching and practical problems of classroom science teaching.

A basic assumption made in the study was that teaching is a type of goal-directed activity. The major goal of science teaching was taken to be the acquisition of scientific paradigms. According to T.S. Kuhn, scientific paradigms constitute what a "scientific community thinks it knows". Since science concepts (i.e. rules governing the use of a term) are inextricably bound to scientific paradigms, the teaching of science concepts was seen as an essential aspect of science teaching strategies. It was pointed out, moreover, that teaching strategies used to teach science concepts are rarely, if ever, firmly based on systematized knowledge of teaching.

Procedure

Development of the methodology was carried forward in four phases: identifying aspects of Smith and co-workers' theoretical work potentially useful for analysing and evaluating the teaching of science concepts; characterizing records of actual teaching strategies; analysing

and evaluating actual teaching strategies for goodness-of-fit with ideal teaching strategies; and suggesting specific problems arising from the study requiring further investigation.

The methodology was developed and illustrated using actual teaching strategies employed by an instructor in a first-year university physics course. The teaching strategies utilized covered a time span of eleven lectures and were directed toward an understanding of eight different science concepts. The eight concepts taught were: "Mass", "Law in Physics", "Electricity", "Electric Field", "Number of Field Lines", "Feedback", "Wave Superposition", and "Nuclear Binding Energy".

Findings of the study

A general conclusion of the study was that the theoretical framework used in the study appeared to be potentially useful for analysing and evaluating certain aspects of classroom teaching. The "venture" and "move" categorizations of the framework proved tractable for analysing and evaluating actual teaching strategies performed in a lecture-type teaching situation. Difficulty, however, is likely to be encountered if the "play" categorizations, at the present stage of development, were to be included in the methodology.

Classifying and organizing the information introduced by the various "moves" in a teaching strategy, in terms of the "functions to be accomplished in teaching a concept", appeared useful not only for deducing "rule-formulations" (i.e. rules governing the use of a term naming the concept) but also for evaluation purposes. In the eva-

luation process teaching functions which appear to be inadequately performed, because the appropriate information was not presented or because the "moves" were defective in some way, were identified. It was pointed out that suggestions for altering a particular teaching strategy in order to include the necessary information or to modify particular "moves" would require experimental investigations into the most advantageous teaching strategy for producing specified learning outcomes for a particular group of students.

The results of analysing and evaluating teaching strategies aimed at teaching concepts as illustrated in the study was seen as potentially useful information for a classroom teacher. However, it was emphasized that identifying the "intended product" of a teaching strategy (i.e. expected rule-formulations deducible from information presented in teaching a concept) is most difficult.

Although the methodology developed was only applied to concept teaching it would appear to be generalizable to other kinds of teaching. Finally, four problems arising from the study and deserving further investigation were identified and described. The problems, viewed as ranging along a hypothetical-practical continuum, were: difficulties encountered in employing the "play" categorizations; a suggested expansion of the "conceptual venture" idea; devising teaching strategies for concept teaching by considering "teaching functions" in terms of the "point-at-ability" of a concept; and a suggested use of the methodology for devising a "Handbook of Teaching Strategies for Selected Science Concepts."

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ACKNOWLEDGEMENTS

I am deeply indebted to Professor Walter B. Boldt for his constructive criticism, rigorous analysis and guidance in every stage of this study. A special thank you also goes to him for his kindness and guiding hand throughout my graduate studies.

Special acknowledgement goes to Professor Walter W. Westphal for his encouragement and refreshing approach to teaching.

My appreciation is expressed to Professor Jerrold R. Coombs for suggesting a more penetrating look at teaching behaviour and for stimulating discussions throughout the study. To Professor L.B. Daniels I extend my gratitude for helping me think through later phases of the study.

To my fellow graduate students and Physics Education Evaluation Project members, thank you for listening and discussing the issues involved in this work.

I would also like to thank Mr. David Linquist for assistance in recording the lectures used for the study. The assistance of Miss Linda Cuthbert for typing innumerable drafts of the thesis is most warmly appreciated. Finally, to my wife, thank you for tolerating the numerous problems and complications inherent in producing a thesis.

DEDICATED

To Elephants and Crocodiles Generally

and

To a Special Elephant

CHAPTER I

THE PROBLEM AND ITS CONTEXT

1.00 Introduction

Smith et al (1962, 1967), followed by Coombs (1969), studied teaching strategies[1] with respect to various subject matter goals achieved and the logical operations used to achieve the teaching goals. The authors identified a number of teaching strategies which can lead, logically, to different teaching goals. The work of these researchers make it possible to assess, on logical grounds, the goodness-of-fit of an actual teaching strategy to an idealized teaching strategy as indicated by a teaching goal. Included in their study are procedures and criteria for observing and analysing actual teaching behaviour in the classroom.

The major concern of the present study is the development of a method, utilizing the results obtained by these investigators to evaluate the match between actual teaching strategies and idealized teaching strategies for particular teaching goals in an actual classroom situation at the University level, and an exploration of the educational implications of the goodness-of-fit.

The thesis is organised into six chapters. Chapter I describes the educational context of the problem under consideration in the study, the nature of the problem investigated, an overview of pro-

cedures used to carry the study forward, and limitations to the study. Chapter II presents a description of special terms used and the theoretical framework underlying the study. Chapter III presents the procedures used in the study. Included in the Chapter is a description of the procedures used to obtain data on actual teaching strategies and goals in an actual classroom situation, and the procedures used to characterise and analyse teaching strategies in order to evaluate the match between actual and ideal teaching strategies. These procedures constitute the "methodology" for analysing and evaluating teaching strategies which has been identified as the major purpose of the present study. Chapter III also contains a description of data used in the study.

Chapter IV presents an illustration of the methodology for analysing and evaluating the teaching of science concepts. Chapter V explores some possible educational implications of the study in light of the theoretical framework underlying the thesis. Included in the Chapter are suggestions for analytic and empirical investigations which could be used to extend the usefulness of this study in meeting problems of classroom practice. The thesis concludes with Chapter VI which summarizes the work presented and suggests improvements to be made in future studies of the kind presented here.

1.10 Context Of The Study

Among the group of contemporary philosopher-historians of science are those (Kuhn, for example) who view uniqueness of science in terms of puzzle-solving activities. Scientific puzzles, like puzzles in playing chess, are theory-determined problems that serve to test the

ingenuity or skill of a scientist in applying the "rules of the game" for attaining a particular solution. For the mature sciences (i.e., physics, chemistry, and biology) puzzle-solving is based on knowledge and experience with accepted models of scientific achievement (Kuhn, 1962, p. 42).

From this view of science the education of scientists is seen as a rigid indoctrination into a pre-established tradition of scientific research, (Kuhn, 1963, p. 345). At the university, undergraduate and graduate science courses are designed to display and provide practice is using scientific paradigms, i.e., the quasi-models to guide scientific research. The nature and sequencing of courses in physics, for example, affirm this function (University of British Columbia, Faculty of Science Calendar, 1969-1970). Starting from introductory courses which display the elementary paradigms of physics, the courses required of future physicists direct the student through detailed explorations of the more complex paradigms of physics. At the individual course level, one can find an introductory course in physics, even for a more general student audience, emphasizing knowledge and understanding of scientific paradigms.

Another important aspect of scientific education is the textbook. Textbooks function as a major pedagogical vehicle in scientific training. "Textbooks treat the various experiements, concepts, laws and theories of the current normal science as separately and as nearly seriatum as possible, in order to acquaint the student with what the contemporary scientific community thinks it knows" (Kuhn, 1962, p. 139).

In other words, textbooks display what is important for a scientist to know -- explicitly and implicitly -- through displaying quasi-models for research and through practice in the use of these models in solving puzzles.

Glancing through sets of science textbooks, one immediately notices the commonality of content (Easley, 1967). The content included seems to suggest a consistently similar view among scientists as to what the novice should learn (Roll, 1968). Also apparent is the inconsistency of pedagogy between texts or the lack of a consistent view on pedagogical matters. For instance, Jay Orear in his elementary textbook, Fundamental Physics (2nd edition, 1967), includes basically the same content as Franklin Miller Jr., in College Physics (2nd edition, 1967). But, Orear places greater emphasis, from a pedagogical viewpoint, on the "first principles or fundamental laws of nature" (Orear, 1967, xp. xiii) rather than presenting "the topics of physics in a semi-traditional sequence which preserves a logical structure" found in Miller's textbook (Miller, 1967, p. v).

The justification given for taking a particular pedagogical approach in a university science textbook usually consists of "it has been my experience that..." (Orear, 1967, p. xv), or "based on five years of feedback from students and teachers..." (Orear, 1967, p. ix). In neither case does the pedagogy seem to be based on educational research or theoretical views of teaching.

A number of advantages could accrue from taking a pedagogical approach based on systematized sources of knowledge. According to

Broudy (1965), theoretical frameworks may provide interpretive maps (theoretical constructs) for identifying an appropriate technology. Included in such a technology are strategies for teaching and learning. A theoretical consideration of teaching serves as a source of ideas which can be used to formulate and justify teaching strategies for attaining specified objectives (Broudy, 1965). More specifically, with a knowledge of the conceptual basis underlying a teaching strategy, one can use the teaching strategy to best advantage without overstepping its inherent limitations. For example, the lecturing technique is most helpful for transmitting large quantities of information, but students with educational deficiencies do not do well in lecture situations (Ryan, 1969).

The instructor in a university science course, as far as the scientific community is concerned, performs functions very much like those of a textbook in science (Kuhn, 1962). He endeavours to display more fully the paradigms presented in the textbook and selects appropriate exercises to emphasize specific aspects of the paradigms. Having mastered the paradigms himself, and demonstrated competence in puzzle-solving at the research level, the instructor is in a strong position to display what is involved and implied in the paradigms. However, because his studies do not generally extend beyond the limits of his discipline, it is unlikely that his pedagogical approach will be based on theoretical views of teaching.

In the few cases where science instructors are asking for help in teaching, the advice given is usually not based on theoretical

views of teaching, but intuitions based on practice. For instance, on the University of British Columbia campus, the Faculty of Engineering organized a teaching/learning seminar to look into ways of improving the teaching of engineering courses; the Physics Department, last year (1969), started an open seminar in teaching; and there have been a series of meetings and symposia on teaching improvement sponsored by various departments on campus; to cite other cases, McGill University's Center for Learning and Development ("Learning and Development" -- newsletters of the Center) is making attempts to improve the University teaching situation; Southern Illinois University organized a program to train future physicists in the teaching of university physics; the Center for Research and Development in Higher Education at the University of California, Berkeley, ("The Research Reporter" -- newsletter of the Center) is looking into ways of improving university teaching generally; and the College of Engineering at the University of Illinois (Urbana) recently completed an attempt to improve instruction in engineering courses (Perlberg and O'Bryant, 1968). But, even in these cases, the suggested teaching strategies are seldom, if ever, firmly based on systematized views of teaching.

In the words of the American Council on Education:

> "the American college teacher is the only high level professional man on the American scene who enters upon a career with neither the prerequisite trial of competence nor experience in the use of the tools of his profession."
>
> (Bleger and Cooper, 1950)

1.20 Statement of the Problem

1.21 The General Problem

Smith (1961) has offered a conceptual framework for viewing teaching which seems to be useful and feasible as a source of ideas for devising teaching strategies in science. Taking the view that:

> "teaching is a system of social actions directed at pupils...All the variables involved in and related to the actions which make up teaching can be placed in three categories [independent variables, intervening variables and dependent variables] but the actions themselves belong to only one of these [the independent variables or teacher actions].
>
> (Smith, 1961, p. 91)

Smith and co-workers (1962, 1967), working within this framework, have "attempted to describe in as objective a fashion as possible, the logical behaviour of teachers as they deal with students and the content of information" (1967, p. 3). In contrast with the Flanders System of analysing teacher behaviour, on which a number of recent systems of analysis have been modelled (Flanders, 1970), Smith and co-workers' focus on the treatment of content in the verbal manipulation of subject matter,[2] while, Flanders centers on patterns of controlling behaviour in verbal interaction between the teacher and the student.

From a survey of the literature (Gage, 1963, for example), no other framework, conceptual view or theory of teaching appears to approach the potential usefulness of Smith and co-workers' conceptual framework as a source of ideas for formulating strategies of classroom

teaching. However, only one reported study (Nuthall, 1968), as far as could be determined, attempted to actualize this apparent potential. Studies on Smith's work (Henderson, 1967; Anderson, 1968; and Coombs 1969; among others) sought to extent and articulate the viewpoint rather than to utilize it as a source of ideas for meeting the problem.

Nuthall[3] attempted to determine if a difference in teaching strategies for two sociological concepts produce measurable differences in student learning and if these differences are related to significant student characteristics. He was able to demonstrate that for two concepts in sociology "the concept of 'teaching strategies' developed by Smith and co-workers can be meaningfully related to student learning, and that elements within a teaching strategy interact with each other and with the knowledge a student already possesses". He concluded that there is a need for "some pedagogically significant method of classifying, for teaching purposes, the kinds of concepts contained in school curricula. But it may not be possible to differentiate between concepts independently of the kinds of strategies which are used to teach them" (Nuthall, 1968, p. 583).

In terms of Smith and co-workers' framework, a significant kind of teaching consists of performing logical verbal operations aimed at achieving particular teaching objectives. One might ask the question, what particular logical operations a science teacher <u>should</u> perform, on logical grounds, to achieve a specific teaching objective? Their framework sets forth a model for performing logical operations in teach-

ing with a particular end-in-view, and it appears potentially fruitful for meeting this problem. One approach to utilizing the model in classroom science teaching would entail an analysis of actual science teaching with a view to identifying conformity to and departure from the logical standards for models of teaching strategies identified by the authors. The results of such an analysis could serve as a source of ideas for devising and revising teaching strategies based on the model.

The general problem, then, is to formulate a method based on Smith and co-workers' conceptual framework of teaching for analysing the actual teaching used to achieve a particular teaching objective in a specific educational context.

This approach to the problem of classroom teaching could serve as a basis for empirical investigations into appropriate strategies for particular objectives and the connection between teaching strategies and learning outcomes in the educational context.

1.22 The Specific Problem

As mentioned previously, a major facet of science teaching especially at university, has to do with teaching scientific paradigms. Some paradigms in science center on concepts while others focus on methods of observation and instrumentation (Kuhn, 1962). The teaching of concepts then, plays an important part in science teaching. For example, in physics one teaches the concept of "electric charge" as a theoretical paradigm basic to solving scientific puzzles having to do with the phenomenon of electromagnetic induction.

By analysing the logical verbal operations in teaching strategies actually employed to teach a concept and assessing the results in terms of the intended objective (i.e., explicating a particular concept), one may be able to suggest on logical grounds whether the strategy employed could lead to the intended objective. Having identified successful and unsuccessful teaching strategies on this basis, for particular objectives, it should be possible to speculate on preferred science teaching strategies for particular teaching objectives, and to offer suggestions for subsequent empirical investigations.

The specific problem proposed for the dissertation is to develop a methodology for analysing and evaluating concept teaching in a university science course using Smith and co-workers' (1967) framework, including revisions (i.e. Coombs, 1969) and to explore the usefulness of the methodology for science teaching.

1.30 Overview Of The Study

The thesis, taken as a whole, constitutes the development and illustration of a methodology which forms a bridge between a theoretical viewpoint of teaching built upon the conceptual framework provided by Smith and co-workers and a practical problem in university science teaching (the teaching of science concepts). There were four phases in the development of the methodology. The first phase involved identifying aspects of Smith and co-workers (1962, 1967) theoretical framework which appeared useful for meeting the problem of analysing and evaluating the teaching of science concepts. Chapter

II illustrates this phase in the methodology. The second phase involved characterizing descriptions of actual concept teaching in science courses at university, by matching the description to descriptive units of the theoretical framework. Chapter IV contains an illustration of this phase, while Chapter III outlines the procedures involved in the phase.

The third phase in developing the methodology required developing procedures for analysing and evaluating the actual teaching of science concepts performed in a classroom situation, from the viewpoint of the theoretical framework. Chapter III outlines the procedures and Chapter IV offers illustrations for using these procedures in analysing and evaluating concept teaching in science at university. Finally, the last phase in developing the methodology involved suggesting specific problems arising from the study which need further investigation. Chapter V indicates four problems identified as different points along a hypothetical theoretical-practical continuum of educational problems. The problems range from difficulties in applying the theoretical framework to potential applications of the methodology in order to resolve particular questions about classroom practice. In the summary Chapter (VI) possible difficulties in applying the methodology are indicated as well as some suggestions for modifying the methodology to meet related problems in science teaching.

1.40 Limitations Of The Study

The study explores the usefulness of a theoretical source of knowledge for dealing with a problem of classroom practice, the

teaching of science concepts. A number of limitations to the study should be recognized. First, the theoretical framework is concerned only with the cognitive aspects of teaching behaviour, that is, the content of instruction and ignores behaviour of teachers in the affective domain. Secondly, the theoretical framework only deals with verbal behaviour in classroom discourse and ignores other aspects of teacher behaviour other than those concrete operations involving the content of instruction. In view of these restrictions on the theoretical view of teaching, the methodology for analysing and evaluating classroom teaching developed in the present study, is limited in application primarily to verbal behaviour in classroom discourse.

In addition to the limitations of generalizability described above, are limitations of applicability of the methodology developed to classroom teaching situations other than the one used in the study. The methodology was developed in the context of a first-year university physics course. According to the philosopher-historian of science T.S. Kuhn (1962), the goal of science teaching, at least at the university level, is typically that of paradigm acquisition. The scientist-teacher is concerned with displaying scientific paradigms and providing opportunities for working with the paradigms in laboratory situations from the standpoint of training competent researchers in science or at least training persons to understand science. It should also be recognized that, in the context within which the methodology was developed, the concepts taught have meanings which are generally agreed upon by scientists. It may be much more

difficult to apply the methodology to the teaching of the more vague concepts in other subject matter areas. With concepts of this sort a difficulty could arise in establishing model teaching strategies for comparison with actual teaching behaviour.

Another limitation of the study has to do with the complexity of the methodology developed. The theoretical framework utilized in the study is couched in the language of philosophy and seems to require some familiarity with epistemology, at least, to understand the framework adequately. Further, the various categorizations of the methodology which were drawn from the theoretical framework require considerable skill and experience in application. These difficulties, together with the problems of establishing ideal ventures and rule-formulations for concepts, would seem to limit the general usefulness of the methodology developed for classroom teaching purposes.

Finally, it should be recognized that the study is limited to being exploratory in nature. It is intended that the study provide an empirical base for subsequent experimental studies in teaching and that an instructor familiar with the methodology presented could use it in attempting to evaluate his own concept of teaching. In view of the present state of knowledge about the applicability of a comparatively recent and important development in the area of classroom teaching, Smith and co-workers theoretical view of teaching, an exploratory study designed to determine how this knowledge might be used in classroom teaching, seems justified.

Footnotes -- Chapter I

[1]A definition of teaching strategies for the purposes of this study is given in thesis Section 2.13.

[2]See Bellack *et al*, (1966) for another content manipulation approach.

[3]Notice that Nuthall is one of the co-workers in the reference Smith *et al*, 1967.

CHAPTER II

A THEORETICAL FRAMEWORK FOR TEACHING CONCEPTS

2.00 Introduction

Chapter II deals specifically with one aspect of the framework developed by Smith and co-workers -- the teaching of concepts. Some of the presentation is based on the work of Coombs (1969), who has extended this aspect of the framework. The first section of the Chapter describes key terms in the theoretical framework used to analyse strategies for teaching concepts. The terms described are: concepts, epistemic rules, teaching strategies, ventures, moves and plays. In the second section of the Chapter the theoretical framework underlying the study is presented.

2.10 Description Of Terms Used

2.11 Concepts

Coombs, in agreement with Green (1968), describes the term concept as "a rule or set of rules governing the use of a term" and "determining what things do or do not belong in a given class" (Coombs, 1969, p. 1).[1] Implicit within this description of concept is a distinction between the name, term or phrase used, and the class or category of things to which the term is used to make reference (i.e., the "referent"; Smith et al, 1967, p. 58). For example, the names "force", "energy", "electricity", "magnetism", and "nuclear forces" are given to certain referents in the field of physics.

A rule, or rules for placing a referent in an appropriate class would be part of the characterization of a concept. For instance, the following rules could be used to describe the concept "scientific law":

(Rule 1) A scientific law is a description of a regularity in nature seen by scientists; and

(Rule 2) subsequently used by them (the scientists) in solving scientific puzzles.

In summary, then, to have a concept is to have "rules for using the term...and rules governing one's behaviour with respect to including or excluding things from the class designated by the term" (Coombs, 1969, p. 1).

2.12 Epistemic Rules

In the teaching of concepts Coombs (1969) describes the term epistemic rule as a set of conditions for appraising the correctness with which a specified teaching function has been performed in accomplishing the teaching of a concept. For example, in teaching concepts, an epistemic rule for guiding teacher action could be "the discussion must adduce a set of criteria (necessary or typical conditions) which are sufficient to warrant the use of the term" (Coombs, 1969, p. 1).

2.13 Teaching Strategies

A number of writers in education have pursued the idea that

classroom teaching resembles a game.[2] In game theory the concept "strategy" is applied to situations where outcomes depend on the action a participant expects others to take, and on what expectations others have of his actions. In the classroom both the teacher as a game-participant and the students as participants act with respect to the action taken by the other. For classroom teaching Smith and co-workers apply the concept "strategy" to the set of verbal actions performed by the teacher and students in the classroom which are directed toward "a cooperative activity that takes the student into the domain of knowledge possessed by the teacher" (Smith et al, 1967, p. 49).

Execution of a strategy by the teacher involves manipulation of verbal activity along two dimensions, treatment and control. The treatment dimension applies to those operations that the teacher (and students) perform in disclosing the content to be learned. Along this dimension, then, the teacher is concerned with the content of instruction -- explaining concepts, analysing casual conditions, pointing out the emotional force of ideas, and the like. The control dimension applies to the operations the teacher uses in an effort to guide and control student participation. For example, the teacher functions along the control dimension by persuading, cajoling, suggesting, demanding, or requesting the students to act in such a manner that they participate in performing operations on the content.

Although the two dimensions are not seen as independent by the writers, their work has centered on the treatment dimension of a teaching strategy. In keeping with this emphasis the term teaching

strategies, for the purposes of the present study, will be taken to mean the control of the subject matter of instruction by the teacher in order to attain certain outcomes or objectives and to guard against others (p. 49).

2.14 Ventures

The authors designate the verbal behaviour occuring during a class session as a total discourse (p. 290). The verbal behaviour of one person at one point in the total discourse is termed an utterance (p. 290). "A segment of discourse consisting of a set of utterances dealing with a single topic and having a single overarching content objective"[3] is referred to, generally, as a venture (p. 6). Eight different classes of ventures have been identified by the authors through an analysis of actual classroom discourses: conceptual, causal, particular, evaluative, interpretative, procedural, reason and rule. The class of ventures termed "conceptual ventures" is the central focus of the present study.

Conceptual ventures have as their overarching content objective or "primary cognitive import" "disclosing the conditions or criteria governing the use of a term" (Smith et al, 1967, p. 294). The terms, to illustrate, may be single words such as "force" or "energy", or an expression such as "nuclear binding energy" or "electro-magnetic induction".

Criteria for identifying ventures, generally, and procedures governing the use of these criteria are presented, for reference, in Appendix B. Criteria for classifying ventures along with instructions

for classifying them have been included in Appendix C.

2.15 Moves

A venture, according to the authors, can be further analysed into units termed "moves" (Smith *et al*, 1967, p. 53). *Move* refers to the verbal activity which introduces one particular bit of information dealing with the venture objective. A teacher, a student, or a teacher and one or more students together may make a move (Coombs, 1969, p. 14). The present study will focus, exclusively, on the moves constituting conceptual ventures.

In the teaching of a particular concept (i.e., in a conceptual venture) a move should help make clear the meaning of the concept. Smith and co-workers (1967, p. 55) view the activities of making clear the meaning of a concept, which are described by the term *moves*, as logical operations aimed at attaining a specific teaching objective.

As a means of illustrating *moves*, consider the following scheme:

> "Let *a*, *b*, *c*, constitute the conditions governing the use of the term *d* [*biological misnomers*], and the objects to which *d* is applicable be denoted by *x*, *y*, *z*.
>
> (Smith *et al*, 1967, p. 55).

By offering instances of *x*, *y*, and *z*, the teacher and students could explicate the term *d*, "biological misnomers". The following three moves might serve this purpose.

Move for x

T: Can you name any other animals that we usually refer to as fish but that do not belong with the fish at all?

S: The whale is a mammal...

Move for y

S: ...The silverfish is an insect.

T: Oh, we studied one and made a drawing of him.

Move for z

S: Crayfish

T: The crayfish. We talked about that a while ago...

(Smith et al, 1967, p. 54)

In eliciting the names of animals (y, z) that have "fish as part of their name, or that are usually referred to as fish (x) the teacher has accomplished the objective of explicating "biological misnomer" (d). These moves serve to bring out the meaning of the term (p. 55).

Activities which introduce different kinds of information about a concept constitute different kinds of moves within a conceptual venture. Fifteen different kinds of moves, logically related to the teaching of concepts, have been identified by the authors (p. 62-82). In extending the authors initial work Coombs reclassified and re-labelled these fifteen moves in concept ventures into fourteen moves. For the purposes of this study Coombs' fourteen moves will be used

(Coombs, 1969). The fourteen moves he designated are described fully in Section 2.22 of the thesis. Procedures for classifying a conceptual venture into moves are given in Section 2.23.

2.16 Plays

Coombs, in his extension of Smith and co-workers work on conceptual ventures, defines a play as a "set of moves which is logically or functionally interrelated" (Coombs, 1969, p. 16). The following example illustrates a set of moves constituting a play:

Move 1

T: In the token demonstration where I separated two oppositely charged objects I was exerting a force on the objects as I moved them apart...

Move 2

T: ...Now, what is a characteristic of what I suggested we call a "force"?

S: For one thing, the force seems to be connected with the motion of separation.

T: Yes, you could tell I was exerting a force on the objects by how the objects moved. In separating them one object was accelerated relative to the other.

The first move in this example is the teacher indicating an instance of the concept "force". In the second move the student points out a characteristic of force, "accelerating one of the objects relative to the other". These two moves constitute a play because they are logically interrelated. The characteristic of a force mentioned in Move 2 -- acceleration of an object -- constitutes evidence or a reason for

regarding the demonstration as a case in point.

Coombs has identified and catalogued plays for conceptual ventures. In Section 2.25 of the thesis is a description of these plays. The epistemic rules for appraising them are presented in section 2.26.

2.20 Theoretical Framework Underlying The Study

In this section of the Chapter a means for analysing the teaching of concepts is presented. Building upon Smith and co-workers analysis of teaching concepts (Smith et al, 1967, pp. 58-95) Coombs extended their analysis of conceptual ventures by:

1. reorganizing the catagoue of concept moves, and
2. considering the functions to be accomplished in teaching concepts.

The latter contribution by Coombs will be discussed first; then, Coombs' catagloue of moves and plays for conceptual ventures, as well as epistemic rules for the catalogue will be described.

2.21 Functions to be Accomplished in the Teaching of Concepts.

Certain implications for the teaching of concepts derive from describing the term "concept" as "a set of rules...". If one assumed that an important goal of teaching a concept is the attainment of the concept by those being taught, then following the aforementioned description of the term "concept", attaining a concept would mean having "rules for using the term which names the concept and rules governing

one's behaviour with respect to including or excluding things from the class designated by the term". (Coombs, 1969, p. 1).

Difficulties in teaching for concept attainment could develop, however, when the rules guiding the use of a particular term do not clearly specify the user's behaviour or the use of the term which names the concept. Those concepts which fit this description would be classified as "vague" according to Green (1968). Green argues that a lack of rules which clearly map the boundaries of a concept, separating it from other concepts, is an important characteristic of vague concepts (Green, 1968, p. 28). For example, in chemistry the term "organic" lacks a clear rule or rules for distinguishing it from inorganic. One rule which has been used for operating with this concept was that a molecule was considered organic if it contained carbon. Yet, a molecule of carbon dioxide (CO_2) contains carbon and is not considered organic.

Coombs (1968) suggests three functions to be accomplished in teaching a concept for attainment whether or not it is vague. These are:

> 1. Make clear how the concept relates to a number of other concepts the student has (provide relational meaning);
>
> 2. Relate the concept to actual events, objects, actions or situations in the students experience (provide experimental reference);
>
> 3. Make clear the context within which the concept has application (provide content).
>
> (Coombs, 1969, p. 1)

As a means of explaining teaching functions consider the follow-

ing example. To teach the concept "gravitational mass" in a physics class the teachser could provide "relational meaning" by relating it to the concept "weight". Gravitational mass, unlike weight, is an unchanging property of a body. The weight of a body -- the pull of gravity on it -- changes, for example, when the object is moved from the earth to the moon. The gravitational mass of the object remains unchanged (PSSC, 1965, p. 327).

The teacher might provide experimental reference for the concept by building upon the following:

> Gravitational mass is what you measure with a beam balance in equilibrium. Two masses that balance on earth will also balance anywhere else -- in a rocket leaving the earth, on the planet Jupiter, or anywhere else in the universe.
>
> (PSSC, 1965, pp. 327-328)

A contextual definition for "gravitational mass" could be:

> It is appropriate to use the term gravitational mass in situations where it makes sense to talk about what is measured by a balance in equilibrium under gravitational forces and where motion is irrelevant.
>
> (PSSC, 1965, pp. 327-328)

2.22 Catalogue of Moves Relevant to Teaching Concepts

In conceptual ventures the concern is with the presentation of information for the explication of the concept. Smith and co-workers (1967, p. 60) identified three major concerns of teachers when explicating a concept:

1. Presenting information which results in students being able to describe the concept (descriptive moves);

2. identifying differences between the concept and some other concept (comparative moves);

3. the direct description of characteristics or qualities of the concept through a discussion of instances (instantial moves).

Coombs (1969) offers moves for a further catagory of teacher concern which involves understanding the use of the concept in reading or learning about more advanced subject matter (usage moves). Coombs (1969) has described and offered an example for moves in each of the four catagories.

Descriptive Moves

1. Characteristic

The referent is described as having a particular characteristic or feature. Example -- concept being taught cerebrum:

T: What is the form of the cerebrum?

S: Spheres.

T: Hemispheres. In other words it is divided into two parts and we call them hemispheres.

2. Sufficient condition

It is pointed out that a given feature or set of features is sufficient to identify something as an instance of the reference class. Example -- concept being taught acid:

T: Now, if you were asked to identify an acid, could you?

S: It has ionizable hydrogen.

3. Classification

The reference class of the concept is identified as a subclass of some more inclusive class of things. Example -- concept being taught habit:

T: How would you define habit?

S: It's an acquired reflex.

4. Subclass

It is pointed out that a given class of things is a subclass of the reference class of the concept. Example -- concept being taught crime:

T: Is a felony one type of crime?

S: Yes.

5. Case Characterization

A case is described and the concept term is used to make a significant statement characterizing the case. Example -- concept being taught socialization:

T: Can anyone tell me what sociolization means?

S: When a kid plays with a group of kids and he starts to think like them, to like what they like and that sort of thing, he's being socialized.

T: Yes, socialization of the child is taking place in that case isn't it?

6. Force

It is pointed out that the concept name has a given emotive, persuasive or evaluative force. Example -- concept being taught propaganda:

S: Doesn't propaganda mean something bad?

T: Yes, we generally think of propaganda as something bad.

Comparative Moves

7. Analogy

The way in which the referent is similar to the referent of some other concept is pointed out. Example -- concept being taught nervous system:

T: What would the nervous system correspond to in a building?

S: The system of electrical wiring.

8. Differentiation

The way in which the referent differs from the referent of some other concept is pointed out here. Example -- concept being taught parole:

T: What's the difference between probation and parole?

S: Parole -- you have to serve part of a prison sentence. Probation -- you don't, but you still have to report practically every week.

9. Contextual Definition

It is pointed out that a given expression employing the concept name is equivalent to another expression. Example -- concept being taught pluralism:

T: Can you tell me what pluralism means?

S: Well, a pluralistic society is -- is a society made up of people with lots of different points of view.

10. Instance Comparison

The similarities or differences between two or more things described as instances of the concept are pointed out. (sub-class comparison). Example -- concept being taught amphibia:

T: Where else do we have a big difference in these animals?

S: The salamander still has its gills but the frog lost its gills from the tadpole stage into the adult stage.

Instantial Moves

11. Positive Instance

Some objects, event or condition is described or pointed out and is identified as an instance of the concept (member of the reference class). Example -- concept being taught satire:

T: This book we're reading is one of the finest examples of a novel that is satire.

12. Negative Instance

Something similar to but not an instance of the concept is described or pointed out and identified as not being an instance of the concept. Example -- concept being taught voluntary act:

S: When something flies at my eyes and I blink, this would be a voluntary act, wouldn't it?

T: No, I don't think so.

Usage Moves

13. Use

The concept name is correctly used in the context of a sentence or a larger utterance. Example -- concept being taught scarcity:

S: It's because of scarcity that we have to make priorities to how we're going to spend the country's money.

14. Meta-distinction

The nature of a concept, the difference meanings a term can have etc., are described or pointed out. Example -- concept being taught imperialism:

T: Some terms like imperialism have more than one kind of meaning. They tell what something is, but they also tell how we feel about it.

(Coombs, 1969, pp. 14-15).

This catagolue of fourteen moves will be used for analysing the conceptual ventures discussed in Chapter IV of the thesis.

2.23 Procedure for Analysing Concept Ventures

Smith and co-workers have suggested the following procedure in analysing a venture:

> 1. The analyst's task is to decide what has been said as distinct from what a teacher or student intended to say, or started to say.
>
> 2. The analyst must decide upon the relation of what has been said to the topic of the venture.
>
> 3. The analyst must decide, from the context of the discussion, whether some parts are subsidiary to other parts or independent units.
>
> 4. The final decision -- the classification of a given section of discourse as a particular kind of move -- is relatively simple.
>
> (Smith *et al*, 1967, p. 56)

These procedures have also been adopted for the purposes of the thesis.

2.24 Epistemic Rules for Analysing Conceptual Ventures

The moves in a conceptual venture should lead to explicating the concept under discussion. Coombs suggests two epistemic rules for analysing a venture. These are:

> 1. The discussion must adduce a set of criteria (necessary or typical conditions) which are sufficient to warrant the use of the concept term. We check to see if we have a set of sufficient criteria by determining whether the criteria allows application of the term in all cases we ordinarily apply it, and rules out its application in all cases we ordinarily

> don't apply it. If it is a technical term its use by the specialist in the technical areas rather than its use by ordinary careful language users is the point of reference.
>
> 2. Within reasonable limits the more sets of sufficient conditions adduced the better. Sufficient conditions provide recognition power. The greater the number of sufficient conditions one knows the greater the chances he will be able to recognize cases in which the concept applies.
>
> (Coombs, 1969, p. 1)

These two epistemic rules form the guides used to analyse concept ventures in the thesis. For examples of their use the reader is referred to Section 4.20.

2.25 Catalogue of Plays Relevant to Teaching Concepts

Moves that are logically or functionally related constitute a play (Coombs, 1969, p. 16). Plays can be separated into two different general classes, "inferential plays" and "non-inferential plays". In the latter plays students are not expected to infer the "rules governing the use of the concept term", rather as many as possible of the characteristics, subclasses of the referents, and such, are named or presented in order to help the student attain the concept.

In inferential plays the student is expected to attain a concept by inferring defining attributes (criteria) of a concept from instances and indicate concept attainment by classifying or using the concept correctly. In one category of inferential plays

"Criterion Inference from Instance Plays", the student is required to show his awareness of the criterion; while, in the other category of plays, "Non-criterion Inference from Instance Plays", the student attempts to demonstrate attainment of the concept directly without showing his awareness of the criterion.

Coombs offers some characteristic plays not as an inclusive set (personal communication to the writer) but as a suggestion of the kinds of logical or functional interrelationships between moves possible in concept ventures. The plays described by Coombs (1969, pp. 16-17) are given below verbatim. For the inferential plays shorthand symbols have been adopted by Coombs.

Shorthand Symbols

PI	=	Positive Instance Move(s)
NI	=	Negative Instance Move(s)
PI Comp	=	Positive Instance Comparison Move(s)
NI Comp	=	Negative Instance Comparison Move(s)
Anal	=	Analogous
Diff	=	Different
Cr	=	Criterial attributes

Non-Inferential Plays

1. Classical Definition

This type of play is a combination of a classification move and one or more characteristic moves. The referent is identified as a subclass of some more inclusive class of the classification by the characteristic moves.

2. Analysis

This type of play is composed of a set of characteristic moves. These moves name or describe a set of parts constituting an exhaustive partitioning of the referent.

3. Sub-class Enumeration

This kind of play includes a number of sub-class moves, and an exhaustive set of sub-classes of the referent is named or described.

4. Instance Enumeration

This play is composed of a set of positive instance moves in which all of the instances of the concept are pointed out.

5. Instance Substantiation

This type of play is comprised of both instance and characteristic moves. A positive or negative instance is pointed out and the reasons or evidence for regarding it as a positive or negative instance are discussed.

6. Contrast

A play of this sort is made up of an analogy move and a differentiation move indicating how the referent is similar to and different from some other concept.

7. Illustration by Instance

In this kind of play one or more features of the referent are described in characteristic moves and then pointed out in one or more cases identified as instances.

Criterion Inference from Instance Plays

8. PI $\longrightarrow$ Cr.

After examining an array of positive instances students are required to infer the criterial attributes.

9. PI + NI → Cr.

After examining an array of positive and negative instances students are required to infer the criterial attributes of the concept.

10. PI Comp → Cr.

Alternate: Students are asked to infer the criteria of a concept from an array of positive instances. They are directed to attend to common features of the instances as possible criteria.

Alternate: After the teacher has pointed out the common features among a number of positive instances, students are asked to infer the criteria of the concept.

11. PI + NI Comp → Cr.

Alternate: Students are asked to infer the criteria of a concept from an array of positive and negative instances. They are directed or encouraged to attend to the features common to positive instances and to the features positive instances do not share with negative instances as possible criteria.

Alternate: After the teacher has pointed out the similarities and differences among a number of positive and negative instances, students are asked to infer the criteria of the concept.

Non-Criterion Inference from Instance Plays

12. PI + NI → Anal + Diff.

From an array of instances of both concepts A (the concept to be learned) and B, students are asked to infer the ways in which A and B are similar and different.

13. PI → Class.

From an array of positive instances students are required to infer the class to which the concept belongs.

These thirteen plays form a catagolue of plays for classi-

fying sets of moves in conceptual ventures. This catalogue has been adopted for the thesis as one of the tools for analysing conceptual ventures.

2.26 Epistemic Rules for Inferential Plays

Coombs (1969, pp. 17-18) offers epistemic rules for "criterion inference from instance plays". The epistemic rules for the plays are:

1. PI $\longrightarrow$ Cr.

   Epistemic Rule: the range of instances must be sufficiently wide that no non-necessary conditions are shared by all the instances.

2. PI + NI $\longrightarrow$ Cr.

   Epistemic Rule (1): Each negative instance should differ from one of the positive instances with respect to only one or as few features as possible.

   Epistemic Rule (2): There should be a range of negative instances such that each criterial attribute is varied.

3. PI comp. $\longrightarrow$ Cr.

   Epistemic Rule: Epistemic rules for this play are the same as for 1. (PI $\longrightarrow$ Cr).

4. PI + NI Comp $\longrightarrow$ Cr.

   Epistemic Rule: Epistemic rules for this play are the same as for 2. (PI + NI $\longrightarrow$ Cr).

Following "non-criterion inference from instance plays" the teacher may find invalid his assumption that students understood criteria. In such cases a teacher would probably offer more instances until there seem to be sufficient information for the students to infer

the concept. "In this version of PI + NI $\longrightarrow$ Cr the total instances advanced by the teacher should meet the epistemic [rules] for the beginning array of instances in PI + Ni $\longrightarrow$ Cr" (Coombs, 1969, p. 21).

2.30 Summary

Smith and co-workers have developed a framework for analysing the teaching of concepts. In discussing their work it is necessary to clarify the use of certain terms: concepts (2.11), epistemic rules (2.12), teaching strategies (2.13), ventures (2.14), moves (2.15), and plays (2.15). The numbers in parenthesis following each term indicate which section of this Chapter contains a description of the term. A discussion of an extension of Smith and co-workers' (1967) analysis of conceptual ventures by Coombs (1969) forms the central focus of section 2.20 of this Chapter. In addition to catalogues of plays and moves, epistemic rules and functions to be accomplished in teaching concepts are discussed. This Chapter, then, is an explication of the theoretical framework to be used in the present study for analysing the teaching of concepts.

Footnotes -- Chapter II

[1]For some concepts it is very difficult to state the "rule or set of rules governing the use of the concept term..." The concepts "red", "love", and "discipline", for example, are difficult to describe in terms of rules, but the concepts are still used correctly.

[2]Ronald E. Hyman (editor), Teaching: Vantage Points for Study, "Section Five: Games", pp. 295-328, 1968.

[3]In a discussion of a topic there are, usually, a number of content elements such as rules, generalizations, descriptions, definitions and facts. The element of content which is the central focus of discussion, that is the "one explicated, established, or set forth by the discussion of the topic as a whole" is what Smith and co-workers designated the "overarching content objective" (Smith et al, 1967, p. 8).

CHAPTER III

PROCEDURES AND DATA USED IN STUDY

3.00 Introduction

The initial part of the Chapter deals with the four phases in the development of the methodology. The resulting procedures not only apply to the specific problem investigated, the teaching of concepts, but also apply to other teaching strategies. The final part of the Chapter presents the data on teaching strategies and goals used to illustrate the methodology developed.

3.10 Four Phases of Development

A method for analysing and evaluating teaching strategies with respect to their corresponding goal is developed in four phases as follows:

Phase 1. Identify aspects of Smith and co-workers (1962, 1967) theoretical framework which appear useful for analysing the actual teaching of science concepts in a first year university physics course.

Phase II. Characterize a record of actual teaching strategies employed in teaching science concepts in a university science course by matching the description to descriptive units (i.e., the catalogue of moves) of the theoretical framework.

Phase III. Analyse and evaluate results of Phase II with a view to devising teaching strategies for specific teaching goals based on logical teaching operations conforming to the teaching models developed by Smith and co-workers.

Phase IV. Suggest specific problems arising from this study having general application to university science teaching which need further investigation.

At the crux of the methodology are the procedures developed in Phase III, the procedures for analysing and evaluating actual teaching strategies performed in a classroom situation from a logical viewpoint. In order to clarify the methodology, each phase is discussed below in the context of teaching science concepts in a first year university physics course.

3.20 Phase I: Identifying Aspects Of Smith and Co-workers' Theoretical Framework

The basic task of this phase is to make explicit the particular concepts, constructs, and classifications of the theoretical framework deemed useful for analysing the teaching of concepts. Aspects dealing with the means of instruction and logical operations involved in performing various teaching acts are identified and described in Chapter II. The particular aspects of Smith and co-workers' theoretical framework described in Chapter II are limited to conceptual ventures and the terminology needed to describe the ventures.

3.30 Phase II: Characterizing A Record Of Actual Teaching Strategies

There are two procedures in the characterization phase. The actual teaching strategies observed are classified into conceptual ventures. Classifications are performed in accordance with Smith and co-workers' procedures and criteria which are identified in Appendices B and C. Then for each conceptual venture identified the moves of the venture are catalogued using the procedures and categories described in Chapter II of the thesis. Chapter IV presents the results of this phase; and for reference, Appendix A contains a part of a transcription of an actual venture which has been identified as a conceptual venture. Moves have been identified and cross-referenced to descriptions contained in Section 2.24 of the thesis.

To illustrate, following the techniques outlined in Smith, et al (1967, Appendix 1; Appendix B of the thesis) each selected lecture is divided into its identifiable overarching content objectives. Teaching strategies in the lecture having a content objective fitting the criteria for conceptual ventures are identified. Then, the conceptual ventures for a lecture are subdivided into moves and the moves for each venture catalogued. Actual teaching strategies performed constitute some of the data used in the next Phase (III).

Reliability of the venture and move classifications performed by the writer was established through a comparison of the writer's classification of actual teaching acts with that of an expert

-- one of the major researchers of the theoretical framework used in the study, Professor J. Coombs.

The initial intent of the thesis was to characterize the conceptual ventures into both moves and plays. The move characterizations were accomplished, but due to the following reasons it became impossible to characterize the selected ventures into plays: First, the concept play was not completely developed at the time of this work and the writer was unable to obtain enough working knowledge about plays to feel confident in applying the play catagorizations. And, the predominant moves identified in the actual ventures did not fit the play catagorizations suggested by Coombs (thesis Section 2.25).

3.40 Phase III: Analysing And Evaluating Actual Teaching Strategies For Goodness-of-fit With Ideal Teaching Strategies.

There are three procedures to this Phase: cull from the instructor's course rationale and other available sources the instructor's hoped-for content objectives or teaching goals (i.e. themes, or conclusions for the subject matter) for the selected lectures; use the data from Phase II to analyse and evaluate the logical teaching operations employed for particular content objectives; and suggest how (on logical grounds) the teaching strategies actually used might or might not lead to the instructor's hoped-for content objectives. The results of this Phase are presented in Chapter IV.

The instructor's content objectives were obtained from a questionnaire he completed prior to each lecture. The details of the questionnaire and other information concerning the course and instruction are discussed in Section 3.70 of this Chapter. The teaching strategies used to achieve a particular content objective were obtained from transcribed audio-tapes of lectures. The strategies identified were subsequently analysed by determining similarities and differences between the model moves described by Coombs (1969) and the actual moves performed and by applying the epistemic rules for moves in conceptual ventures.

Analysing the actual teaching strategies performed in this way, it is possible to establish, on logical grounds, the goodness-of-fit of the actual teaching strategies to the model or ideal teaching strategies. The match between actual and model teaching strategies form the basis for suggesting "how" the teaching strategies actually used might or might not lead to the instructor's hoped-for content objectives. For example, in those cases where the objective is not attained by a particular identifiable teaching strategy a comparison between the actual logical teaching operations and the idealized logical operations, as implied by the content objective for the actual teaching strategy, is performed in order to find out what logical operations were missing or inappropriate.

3.50 Phase IV: Suggesting Specific Problems Requiring Further Investigation

Information, such as that obtained in the example cited for Phase III on the comparison between an actual teaching strategy and the idealized teaching strategy, is used to generate questions for experimental and analytic investigation.

3.60 Data Used To Illustrate The Methodology

In order to demonstrate the methodology, examples of university science teaching have been selected. The lecture segment of an introductory university physics course (Physics 110 at the University of British Columbia 1969-1970) forms the data source for teaching strategies and goals. The course was designed for a heterogeneous population of first year university students not planning to major in physics (approximately 650 students in all; Physics Education Evaluation Project, Interim Report, January 1970, p. 8). The course was divided into separate lecture sections but retained a common laboratory experience. Data for this study was obtained from two lecture sections, both taught by the same instructor.

The instructor willingly permitted and encouraged the collection of the data which was used in this study. To illustrate, he permitted unobtrusive audio-taping of his lectures and the presence of the writer in the lectures; he conscientiously completed a questionnaire describing his teaching goal for each lecture and actively participated in many discussions with the writer concerning his (the ins-

tructor's) teaching goals in the physics course.

Transcripts of a selected set of lectures from the instructor's course form the data source for actual teaching strategies. The transcripts have been made from audio-tapes which were obtained by recording off the public address system during lectures. Additional written information presented in the lecture on overhead transparencies was obtained but was not useful for this study.

Teaching goals for the teaching strategies were obtained from two sources. The instructor of the physics course prepared a course rationale in which he gave his broad goals for the course and some justification for these goals (Physics Education Evaluation Project, Interim Report, January 1970, pp. 10-17). The course rationale serves as a means to focus on the instructor's broad teaching goals. The instructor also completed, prior to each lecture, an analysis of the objectives for the lecture, the importance of these objectives to the course and the lecture, and other information about what he intended to do in the lecture. Pre-lecture analyses form the data source to pinpoint specific content objectives for each lecture. Appendix D contains an example of the pre-lecture analysis form used in the study.

From the approximately one hundred and forty lectures presented in each of two sections of the introductory university physics course, eleven lectures were selected for the purposes of the present study. The lectures represent examples of teaching strategies for each of the eight months of the course excluding the first and last month. The lectures selected met three criteria: First, the instructor

had indicated on the pre-lecture analysis form that he planned to teach a concept; second, a record (audiotape, etc.) of the actual teaching strategies in the lecture had been made; and third, the instructor indicated on the pre-lecture analysis sheet the importance of the concept to the course -- lectures containing concepts which were moderate to very important, as rated by the instructor, were selected. The lectures are the data used in illustrating the methodology.

Table 1 presents the concept terms taught (Concept Name), distribution of concept ventures over time (Month of Lecture), importance of the concept to the course (General Importance of Concept), the number of moves in each conceptual venture (Number of Moves in Venture), and the numerical order in which the concepts ventures are presented in Chapter IV.

TABLE 1. Data On Concept Ventures Selected For Study

Concept Name	Month Venture Performed	General Importance Of Concept*	Number of Moves in Venture	Venture Number
Mass	October	5	5	1
Mass	October	5	17	2
Law in Physics	November	4	6	3
Electricity	November	2	10	4
Law in Physics	December	3	5	5
Law in Physics	January	4	5	6
Electric Field	January	5	9	7
Number of Field Lines	February	2	4	8
Feedback	March	5	6	9
Superposition of Waves	March	4	12	10
Nuclear Binding energy	March	5	7	11

*A composite score of what the instructor stated to be important in the lecture. Scale endpoints are:

5 = very important
1 = minor importance

See text for further information.

CHAPTER IV

ILLUSTRATIONS OF PHASES II AND III IN THE DEVELOPMENT OF THE METHODOLOGY

4.00 Introduction

The Chapter is divided into two major parts corresponding to two phases of development. Part one of the Chapter describes and illustrates Phase II, the characterization of actual teaching strategies, by applying the theoretical framework to eight concepts taught in an introductory university physics course. Phase III is illustrated in the second part of the Chapter. The general approach to analysing and evaluating actual teaching strategies is described; then, the analysis and evaluation procedures are described and illustrated using actual teaching strategies.

4.10 Characterizations Of Actual Teaching Strategies

In the eleven ventures identified for the study, eight different concepts were taught. The eight concept terms are: "Mass", "Law in Physics", "Electricity", "Electric Field", "Number of Field Lines", "Feedback", "Wave Superposition", and "Nuclear Binding Energy". The concept termed "Mass" was taught in two ventures while the concept termed "Law in Physics" was taught in three separate ventures; the remaining concepts were only taught in a single venture.

The possible information contained in these ventures was characterized into moves according to Smith and co-workers' move categorizations. The possible information about the concept presented in each venture has been organized in separate figures for ease of display.

Table 2 is a representation of the possible information about a concept which could be introduced through the various moves. Note first that the moves have been arranged with respect to the functions they might accomplish in teaching a concept. Column one of the Figure represents information providing theoretical or relational meaning for the concept; the second column represents information on experiental reference; and the third column represents information on the context within which the concept has application. Secondly, the moves have been organized into information categories according to the kind of information they provide about the concept. For example, below the information category termed "analogy" analogy and differentiation moves provide information of this type (move numbers 7 and 8 in the theoretical framework, Thesis Section 2.22).

Also note that characteristic and case characterization moves may provide relational meaning and/or experiential reference. For instance, one could describe a watch by saying "one characteristic of a watch is that it is used to tell time." In this type of characteristic move the person has related the concept term "watch" to the concept term "time". Describing the watch by pointing out that "a watch has two hands which move on a face in accordance with the ob-

TABLE 2. Representative Format for Information Presented in Concept Ventures

Concept: [ ]

Venture: [ ] Lecture Date: [ ]

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING A CONCEPT*

Provide-theoretical or relational meaning	Provide-experiental references	Provide-context
- force (6)		
Analogy	Subclass	Necessary and Sufficient Condition
- analogy (7)+	- subclass (4)	- sufficient condition (2)
- differentiation (8)	- positive instance (11)	
- instance comparison (10)	- negative instance (12)	Appropriate Context
Classification	Characteristic	- contextual definition (9)
- classification (3)	- characteristic (1)	- use (13)
Characteristic	- case characteristic (5)	- meta-distinction (14)
- characteristic (1)		
- case characteristic (5)		

* The teaching function accomplished by a particular move depends to some extent on the background information about the concept provided by the student. To that extent, the positioning of move categories in the table is an attempt by the writer to indicate which functions seem likely to be provided by the move categories. However, to determine the exact location of a move in the table empirical studies need to be performed.

\+ The numbers in parenthesis refer to the type of move as described in Thesis Section 2.22.

served motion of the sun" is an example of a characteristic move providing experiential reference.[1]

A distillation of the potential information contained in each venture concerning the concept terms "Mass", "Law in Physics" and "Wave Superposition", is displayed in Tables 3-8. As an aid to the reader for checking how the information displayed in Tables 3-8 was obtained, the following provision has been made: Appendix A contains a transcript of the segment of an actual lecture identified as a conceptual venture (i.e., actual teaching strategies). Teaching the concept termed "Wave Superposition" has been identified as the major teaching goal for this venture. In Appendix A, the letters in the margin next to parts of the transcript are for convenience in cross-referencing with the specific information displayed in Table 8. The numbers in parenthesis next to the letters represent moves identified in the venture.

TABLE 3. Potential Information about the Concept Termed "Mass", Venture 1

Concept Term: "Mass" Venture: 1 Lecture Date: October 1, 1970		
FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT		
Provide-theoretical or relational meaning	Provide-experiential reference	Provide-Context
Analogy D_1 - (7): Mass is similar to weight.		
Classification A_1 - (3): Mass is used in describing causes of motion along with force, and acceleration.	Characteristic B_1 - (5): Appearance of object is one indication of amount of mass. B_1 - (5): Difference in speed between two objects in motion useful for indicating difference in mass of objects. C_1 - (5): Motion after collision slower for greater mass.	Context E_1 - (9): Mass= $\frac{\text{Momentum}}{\text{Velocity}}$ and velocity proportional to distance and therefore mass of object related to distance moved.

TABLE 4. Potential Information about the Concept Termed "Mass", Venture 2

Concept Term: "Mass"

Venture: 2 Lecture Date: October 3, 1970

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING A CONCEPT

Provide-theoretical or relational meaning	Provide-experiential references	Provide-Context
Classification	Characteristic	Context
F_2 - (3): Mass, like force is a concept used in dynamics, an area of mechanics	H_2 - (1): Objects which are identical have the same mass. I_2 - (1): Mass of two objects added together is sum of individual masses J_2 - (5): Ratio of velocities of objects given same push is a means for measuring the relative masses of objects. L_2 - (5): In measuring relative masses by comparing velocities objects must both start from rest. C_2 - (5): Size of object can make a difference in it's mass.	E_2 - (4): Mass= Force. Acceleration K_2 - (9): $\frac{Mass_1}{Mass_2} = \frac{Velocity_2}{Velocity_1}$ K_2 - (9): Direction of Movement affects mass measurement D_2 - (9): Mass = Density x Volume. B_2 - (14): Give secure feeling by knowing where one knows information. G_2 - (14): Defining the term "mass" is not equivalent to the derivation of the concept.

TABLE 4. (continued)

Concept Term: "Mass (continued)

Venture: 2 Lecture Date: October 3, 1970

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING A CONCEPT		
Provide theoretical or relational meaning	Provide-experiential references	Provide Context
	C_2 - (5): Distance object thrown can be used as measure of mass of object by considering distance proportional to speed and making comaprison between objects when given same push (momentum of each).	G_2 - (14): Look for definition which describes situation most simply. A_2 - (13): Applies to material objects.

TABLE 5. Potential Information about the Concept "Law in Physics", Venture 3

Concept Term: "Law in Physics" Venture: 3 Lecture Date: November 18, 1970		
FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT		
Provide-theoretical or relational meaning	Provide-experiential reference	Provide-Context
Analogy B_1 - (8): Law is used differently in society and physics a. societal law could be different b. law in society is a convention c. law in physics independent of what humans do d. law in physics holds whether or not humans interfere.	Subclass D_1 - (11): Kepler's Laws are an example of Laws in Physics	Context A_1 - (6): Law is of main importance in physics.
Characteristic E_1 - (5): Law describes structure in nature. C_1 - (5): Objects obey certain structure in their behaviour.	Characteristic F_1 - (5): Scientists believe in general validity of a law.	

TABLE 6. Potential Information about the Concept Termed "Law in Physics", Venture 5

Concept Term: "Law in Physics"		
Venture: 5 Lecture Date: December 2, 1970		
FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT		
Provide-theoretical or relational meaning	Provide-experiential reference	Provide-Context
Characteristic	Characteristic	Context
E_2 - (1): Probe law by looking for cases which do not obey the law.	A_2 - (1): Experience shows nature behaves that way. B_2 - (1): Nature's behaviour not a choice of observer. C_2 - (1): Law stated so that only one contradictory experience is needed to disprove it.	D_2 - (14): Exception proves a rule but proving actually means probing.

TABLE 7. Potential Information about the Concept Termed "Law in Physics", Venture 6.

Concept Term: "Law in Physics"		
Venture: 6 Lecture Date: January 7, 1970		
FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT		
Provide-theoretical or relational meaning	Provide-experiential reference	Provide Context
Analogy C_3 - (8): Differentiation between definition and law. a. definition is just name, no observation needed. b. arbitrary statement like person's first name. E_3 - (8): Law can be disproved but definition cannot be proved.		
Characteristic A_3 - (1): Nature behaves that way. A_3 - (1): Structure found in nature.	Characteristic B_3 - (1): Single contradictory experience or experiment disproves general validity of the law. D_3 - (1): Same as B_c - (1).	

TABLE 8. Potential Information about the Concept Termed "Wave Superposition" Venture 10.

Concept Term: "Wave Superposition"

Venture: 10 Lecture Date: March 3, 1970

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT

Provide-theoretical or relational meaning	Provide-experiential reference	Provide-Context
	Subclass B - (11): Standing waves are example of wave superposition C - (11): This pointing to example is a standing wave.	
Characteristic E - (1): When two waves pass same point at same time always superimpose L - (5): Where waves superimpose there is point does not move called node.	Characteristic A - (5): Waves deflected back and returning along same path will superimpose with waves still on path. F - (5): Waves travelling opposite direction along same surface will add up when meeting. G - (5): Cancelling out is a type of adding up. H - (5): Resulting wave pattern when waves meet is addition wave pattern of one wave and that of another. J - (5): Combining amplitudes is means of adding up.	Context I - (13): For mechanical waves superposition only applies to small amplitude waves; applies for all electro-magnetic waves.

4.20 Analysis And Evaluation Of Actual Teaching Strategies

An analysis of information introduced in a teaching strategy concerned with a concept yields "rules governing one's use of the concept term and one's behaviour with respect to including or excluding things from the class designated by the term" (Coombs, 1969, p.1). The rule-formulations (i.e. statement of the rule) elicited from the information introduced by the moves in an actual conceptual venture. From the viewpoint of the theoretical framework the "intended product" of concept teaching is a complete set of rule-formulations for each concept taught.

The analysis procedure, then, involves deducing rule-formulations which are the "potential product" of an actual teaching strategy and deducing the rule-formulations constituting the "intended product" through analysis of the corresponding model conceptual venture, or ideal teaching strategy. In the subsequent evaluation procedure the "intended product" is compared with the "potential product" and suggestions made for improving the match between them.

Subsection 4.21 illustrates an analysis procedure resulting in an identification of the "potential product". Subsection 4.22 illustrates a procedure for obtaining the "intended product". Subsection 4.23 illustrates the matching step in the evaluation procedure. Finally, subsection 4.24 indicates some suggestions for improving the match between ideal and actual teaching strategies.

4.21 Analysis Procedure Yielding A "Potential Product" From An Actual Teaching Strategy.

An epistemic rule has been formulated to serve as a guide for eliciting the rule-formulations of a concept from the information presented in actual teaching strategies. The epistemic rule is:

> The statement of each rule used in the description of a concept must be such that the rule accurately reflects the meaning and implications about the context of the concept term inferred from information in a venture.

The epistemic rule is used to determine if information presented by the instructor in a venture has been interpreted correctly in the analysis procedure. The test for correctness of interpretation is whether the description of a concept deduced from the venture is accurately displayed in the form of "a set of rules governing the use of the [concept] term" and "determining what things do or do not belong in a given class" (Definition of a Concept, Coombs, 1969, p. 1).

As an illustration of the analysis procedure consider the following description of the concept called "Wave Superposition". Information presented in the form of moves in the venture concerned with "Wave Superposition" was characterized in Phase II into three categories according to "the function to be accomplished in teaching a concept": Providing relational meaning, providing experiential reference, and providing context. The displayed information, Table 7, is analysed by extracting key phrases or ideas which help to describe or define the concept.

For instance, the information; "for mechanical waves superposition only applies to small amplitude waves; applies for all electro-magnetic waves" suggests ideas for formulating a rule to distinguish what things do or do not belong to the class designated by the term "Wave Superposition". One formulation of the rule might be: "The class of things having the property 'Wave Superposition' should be limited to small-amplitude mechanical waves and all electro-magnetic waves." Another formulation of the same rule might be: "Mechanical waves other than those having small amplitudes are not to be placed in the class of things which have the property 'Wave Superposition' but the term applies to all electro-magnetic waves."

The epistemic rule is brought to bear on these rule-formulations by suggesting a further search for meanings and implications not already present in the rule, which could be inferred from the information given. Since the two rule-formulations stated above, accurately reflect, as far as can be ascertained from the information given, the meaning and implications of the concept term "Wave Superposition" in the context given they constitute a "potential product" of at least this part of the venture.

Rule-formulations for the eight concepts contained in the selected ventures are presented in Table 9. The first column indicates the concept term. The second column indicates the teaching function accomplished if the rule-formulation is the product of teaching the con-

TABLE 9. The "Potential Product": Rule-formulations for Actual Teaching Strategies

Concept Term	Function Provided in Teaching Concept	Coded Section of Venture	Rule-Formulations *
Mass	E.R. (Experiential reference)	B_1, H_2	(1) The appearance of an object can be used to give an induction of its mass.
	R.M. (Relational Meaning)	H_1, F_2	(2) The term mass is used only when speaking about causes of motion (dynamics).
	E.R.	C_1, E_1, J_2, L_2, A_2	(3) The measurement of an object's inertial mass can be performed by comparing the velocity of one object relative to another when both are started from rest with identical push.
	Cont. (Context)	E_2, D_2	(4) Mass is used in conjunction with other terms like force and density in order to describe a particular property of matter or to explain the motion of matter.

TABLE 9. (continued)

Concept Term	Function Provided in Teaching Concept	Coded Section of Venture	Rule-Formulations
Law in Physics			(1) The term "law" is applied to a description of a structure found in nature.
	R.M. + E.R.	B_1, B_2, A_2	(2) A law is not an arbitrary choice of an observer, but a description based on experience.
	R.M. + E.R.	C_2, E_2, B_3	(3) A law must be stated so that a single contradictory experience or experiment disproves the general validity of the law.
	E.R.	F_1	(4) In the statement of a law there is implicit the assumption or belief in its general validity.
			(5) To check the validity of a law, scientists probe the law by looking for cases which do not obey it.

TABLE 9. (continued)

Concept Term	Function Provided in Teaching Concept	Coded Section of Venture	Rule-Formulations
Superposition of Waves	R.M.	A	(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions.
	E.R.	E	(2) When two waves pass the same point at the same time the concept term applies.
	E.R.	F,G,H,J	(3) Adding the amplitude of two waves is called superposition of waves.
	E.R.	F,G,H,J	(4) When two waves superimpose they are in the class of things to which the term wave superposition may be applied.
	Cont.	I	(5) The term only applies to small amplitude mechanical waves but the term applies to all electromagnetic waves.

TABLE 9. (continued)

Concept Term	Function Providing in Teaching Concept	Coded Section of Venture	Rule-Formulations
Superposition of Waves (continued)	R.M.	L	(6) If waves superimpose, at least one point along the wave will not move: This point is called a node.

*Based on a pooling of information in the ventures involving the concept terms "mass" and "Law in Physics", respectively.

cept. The third column contains letters representing the section of the venture shown in Tables 3 - 8 which formed the information used to deduce the rules for each concept taught. For the concept termed "Wave Superposition"; for example, the letters represent the section of the venture from which information about the concept was abstracted, condensed and presented in Table 8. The letters for this concept are also indicated next to sections of the actual transcript shown in Appendix A. The last column contains the rules formulated for the concepts as deduced from information contained in the ventures.

4.22 Analysis Procedure Yielding an "Intended Product" From An Ideal Teaching Strategy.

The overarching content objective for a conceptual venture is the disclosing of conditions or criteria governing the use of the term (Smith et al, 1967, p. 294). For a model conceptual venture (ideal teaching strategy concerning concepts) according to the theoretical framework, sufficient criteria or conditions must be disclosed to warrant the use of the concept term. The epistemic rules suggested by Coombs (1969, p. 1; also Thesis Section 2.25) serve as a guide in developing criteria. Such a set of criteria are the "intended product" of an ideal teaching strategy. In the form of rules governing the use of the term they are comparable to the rule-formulations resulting from an analysis of actual teaching strategies. In summary, then, this subsection presents a procedure which can be used to yield intended rule-formulations from ideal teaching strategies that meet the epistemic rules suggested by Coombs.

The theoretically possible information about a concept which could be introduced through moves in a conceptual venture has been displayed in Table 2. The kind of information each move can provide in teaching a concept is the starting point for proposing intended rule-formulations for the conceptual venture carried out by the instructor. Note, however, that the concern is with information at the level of abstraction identified by the instructor and the textbook for the course as suitable for first-year university physics students. Information for this purpose was obtained from first-year physics textbooks, the actual teaching strategies, statements of the instructor's intended goals (i.e. Appendix D, the Pre-lecture Analysis Form), and other members of the Physics Faculty involved in undergraduate physics courses. The resulting information is then classified into moves and the moves characterized according to the teaching functions which could be accomplished in teaching the concept.

The characterized information is used to formulate "rules governing the use of the term...". Each rule-formulation is checked for correctness by applying the epistemic rule described in Thesis Section 4.21. The set of rule-formulations obtained in this way is checked for completeness by applying the epistemic rules described in Thesis Section 2.25. The "intended product" then, is a set of rule-formulations or criteria sufficient to warrant use of the concept term.

As an illustration of the procedures the concept termed "Wave Superposition" has been selected. Table 8 presents information obtained from characterizing the actual teaching strategy for this con-

cept. Rule-formulations of the concept were deduced from the information and are presented in Table 9. The rule-formations obtained in this way constitute a possible subset of the ideal set of rule-formulations for the concept term -- the "intended product" of teaching the concept. Additional rule-formulations are now sought in order to have a set of criteria sufficient for using the concept term. We seek to formulate necessary or typical rules which are sufficient to allow application of the term in all situations to which it is typically applied in first-year university physics course and rules which eliminate application of the term in all cases not appropriate to this school level.

For example, Orear (1967, p. 242) indicates that when a single wave pulse is set in motion from one end of a taut string and simultaneously a single wave pulse is started at the other end, "the two pulses will cross through each other and continue to proceed in their own directions," unchanged in shape and velocity. The additional information is that the waves continue after crossing as if unaffected in the crossing event. Orear points to this occurance as the characteristic of "Wave Superposition" ("consequence of the Principle of Superposition", in Orear's terms, 1967, p. 242). Since the information provides a characteristic feature of the concept that is potentially observable by students, the information could be characterized for teaching purposes, as providing experiential reference.

A rule-formulation deduced from the information could be: Superposition of waves does not affect the initial form of

the waves.

Another rule-formulation concerning wave superposition could be deduced from information supplied by Miller (1967). Miller specifies an important contextual limitation is applying the term "Wave Superposition". To use Miller's (1967, p. 217) words, there is "a definite assumption about a medium when we involve the superposition principle of waves of some sort in a medium." An example of such an assumption is the idealization that for pulses on a coil spring, the coil spring must be perfectly flexible, have no internal resistance, and be kept in a vacuum. In the actual teaching strategy the information concerning large amplitude mechanical waves does not seem to imply the same necessary rule-formulation. Not enough information was given about why the principle applies only to small amplitude mechanical waves. The rule-formulation deducible from combining Miller's information and that presented in Table 8 is: The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which case deviations from ideal conditions of the medium are or can be considered to be negligible.

The epistemic rules in Thesis Section 2.25 are applied to the rule-formulations presented in Table 9 in combination with the two additional rule formulations stated above, by ascertaining whether the rules as formulated are sufficient to warrant using the term "Wave Superposition". Examination of typical cases to which the term is

applied in the two first-year university physics texts mentioned above, and the transcript of the venture for the concept, reveals that the term is only applied to ideal cases -- idealized springs, strings, liquid surfaces -- and electromagnetic fields, and not to situations that oceanographers or engineers, for example, have to deal with. The rule-formulation given above allows application of the term "Wave Superposition" to typical cases and rules out application to atypical situations with significant deviations from idealized conditions such as waves along real springs, real strings held loosely, and real liquid surfaces. The rule formulated above, therefore, can be considered part of the "intended product" of the ideal teaching strategy for the concept called "Wave Superposition". The "intended product" for the ideal teaching strategy of each concept can be formulated by the procedure indicated.

In Table 10, column 1, contains the concept term; column 2 presents the source of the additional information; and column 3 contains a summary of the information needed in addition to that presented in Tables 3 - 8. The rule formulated from the additional information, teaching function to be accomplished by using the information, and a tentative move category are presented in columns 4 to 6 of Table 10, respectively.

The rule-formulations given in Table 9 combined with those given in Table 10 represent the "intended product" of ideal teaching strategies of each concept described. The complete set of rule-formulations for each concept -- the "intended product" -- is presented

TABLE 10. Additional Rule-Formulations Derived From Information Other Than Actual Teaching Strategies.

Concept Term (1)	Source of Information (2)	Additional Information (3)	Rule-Formulations (4)	Function in Teaching (5)	Move Category (6)
1. Mass	Miller, (1967 p. 70)	There are different types of mass depending on what property of matter is being considered.	Mass is a general term describing a property of matter.	E.R.*	4
	Miller, (1967, p. 70) and Orear, (1967, p. 55).	Examples of types of mass are: inertial, gravitational, relativistic, and rest mass.	Terms specifying the type of mass analysed are prefixed in to the term mass. These are inertial, gravitational, relativistic, and rest mass.	E.R.	11

TABLE 10. (continued)

Concept Term (1)	Source of Information (2)	Additional Information (3)	Rule-Formulations (4)	Function in Teaching (5)	Move Category (6)
2. Law in Physics	Kuhn, (1962), Thesis Section 2.11.	Scientists use laws to solve scientific puzzles.	Laws are used by scientists to solve scientific puzzles.	E.R.	5
3. Wave Superposition	Orear, (1967 p. 242).	Two pulses cross through each other and continue to proceed in own direction unchanged in shape and velocity.	Superposition of waves does not affect the initial shape and velocity of the waves.	E.R.	1 or 5

TABLE 10. (continued)

Concept Term (1)	Source of Information (2)	Additional Information (3)	Rule-Formulations (4)	Function in Teaching (5)	Move Category (6)
3. Wave Superposition (continued)	Miller, (1967, p. 217).	Important assumption about a medium are made when invoking the superposition principle for waves.	The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which deviations from ideal conditions of the medium are negligible.	Cont.	13

* These abbreviations are explained in Table 3

Refers to move categories described in Thesis Section 2.22

in Table 11.

4.23 Evaluation Procedure

Matching rule-formulations of the "potential product" to rule-formulations of the "intended product" in order to identify missing, ambiguous, incomplete or redundant rules in the former, is the first step in the evaluation procedure. The second step is to specify a move or moves which should be performed in order to produce the missing rules. Choosing a move may be facilitated by considering the nature of the teaching function to be provided (i.e. Table 2). Finally, model moves are suggested which could be performed in order to meet the function proposed.

Again, the concept called "Wave Superposition" will be used to illustrate the steps in the procedure. Table 9 contains the set of rule-formulations comprising the "potential product" and Table 11 contains a set of rule-formulations comprising the "intended product" for illustration purposes.

The rule formulations in Table 9 and Table 11 are compared.

Table 9 "Potential Product" Rule Formulations	Table 11 "Intended Product" Rule Formulations
Rule 1	Rule 1
2	2
3	3
4	4
5	5
6	6
-	7
-	8

TABLE 11. The "Intended Product"

Rule-Formulations for Ideal Teaching Strategies

Concept Name	Rule-Formulations
Mass	(1) The appearance of an object can be used to give an indication of its mass. (2) The term mass is used when speaking about causes of motion (dynamics). (3) The measurement of an object's inertial mass can be performed by comparing the velocity of one object relative to another when both are started from rest with an identical push. (4) Mass is used in conjunction with other terms like force and density in order to describe a particular property of matter, or to explain the motion of matter. (5) Mass is a general term describing a property of matter. (6) Terms specifying the type of mass are placed in front of the term mass. These are: inertial, gravitational, relativistic and rest.
Law in Physics	(1) The term is applied to a description of a structure found in nature. (2) A law is not an arbitrary choice of an observer, but a description based on experience. (3) A law must be stated so that a single contradictory experience or experiment disproves the general validity of the law. (4) In the statement of a law there is implicit the assumption or belief in its general validity.

TABLE 11. (continued)

Concept Name	Rule-Formulations
Law in Physics (continued)	(5) To check the validity of a law scientists probe the law looking for cases which do not obey it. (6) Laws are used by scientists to solve scientific puzzles.
Wave Superposition	(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions. (2) When two waves pass the same point at same time the concept term applies. (3) Adding up of two waves crossing is called superposition of waves. (4) When two waves superimpose they are in the class of things to which the term applies. (5) The term only applies to small amplitude mechanical waves but applies to all electromagnetic waves. (6) If waves superimpose at least one point along the wave will not move. That point is called a node. (7) Superposition of waves does not affect the initial shape and velocity of the waves. (8) The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which case deviations from ideal condition of the medium are negligible.

It is evident that rules 7 and 8 in Table 11 are not present in Table 9. However, rules 5 and 8 (Table 11) describe similar features of the concept (restrictions for the type of wave one may use with the concept term), but rule 5 is not as complete as rule 8.

The next step is to specify particular moves based on teaching experience which when performed would present the information needed to deduce the missing rules. For instance, in Table 10, column 5 contains suggestions for providing information which should result in producing the missing rules. For rule 7 as suggested in Table 10, the rule might be deduced by moves containing information which provides experiential reference (E.R.). For rule 8 providing context (Cont.) might be the appropriate teaching function accomplished. The particular type of move which could serve the teaching function is indicated in the same Table (column 6). For rule 7 either a characteristic move (1) or a case characterization move (5) would be appropriate. For rule 8 a usage move (13) could accomplish the teaching function. The same procedure can be applied to the concept terms "Mass" and "Law in Physics".

4.24 Suggestions For Improving The Match Between Actual Teaching Strategies And Ideal Teaching Strategies.

The suggested move types (Table 10, column 6) can be used as a guide for suggesting new teaching activities which should be added to the actual teaching strategy; or, these move categories can be used as a guide for suggesting modifications to existing teaching activities which already had been classified as a particular move. Both suggestions could

serve to improve the actual teaching strategies by bringing them more in line with the ideal. The actual teaching strategies for teaching the concept "Wave Superposition" evaluated and discussed in Thesis Section 4.23 will serve as an illustration of ways to use the developed methodology for improving teaching.

The actual teaching strategy for "Wave Superposition" could be modified slightly in order to integrate into it the information needed to deduce the two additional rule-formulations (Table 10). The information concerning wave independence (Table 11, column 3) could be integrated with coded section F of the actual lecture transcript (Appendix A). Since this section was catalogued as a case characterization move, a phrase indicating the independent nature of the crossing waves in the case cited would be sufficient. Another way of introducing the same information would be in the form of a characteristic move placed between coded sections E and F (Appendix A). The move might be stated in the same words used in the rule-formulation. For the information concerning the nature of the medium, the "usage move" presenting information about mechanical and electromagnetic waves (Section 1-13, Appendix A) might be expanded to include the information on medium. For example, the rule concerning transmitting medium could be deduced from the phrase: "A large amplitude wave would be one which permanently deformed the medium through which the wave travelled -- like -- shock waves breaking a crystal glass".

These modifications to the teaching strategy concerning "Wave Superposition" are only examples of possible ways of improving the match

between actual and ideal teaching strategies. The specific teaching strategy proposed (including the suggested additions) should be logically sound and would require an experimental verification of the effectiveness of the strategy for meeting specified teaching goals. An instructor's task would involve determining which rule-formulation he can assume the students already have and which rule-formulations the students must deduce from information introduced in the teaching strategy. In this way, he could decide how to organize his teaching in order to maximize the clarity and precision of the "potential product".

4.30 Summary

The Chapter contains illustrations of Phase II and III in the developing methodology. For Phase II the characterization of actual teaching strategies entails the following procedures: categorizing a conceptual venture into moves, organizing the information in the moves with respect to the functions they accomplish in teaching the concept and displaying the organized information in summary form (Table 2). Phase III requires four procedures. In the analysis of teaching strategies, two procedures are involved; deducing rule-formulations describing a concept which are the "potential product" of an actual teaching strategy and deducing rule-formulations from other sources which when integrated with the "potential product" are the "intended product" of an ideal teaching strategy for the same concept. In the evaluation procedure of the Phase the "intended product" and the "potential product" are matched.

In the final procedures of Phase III a specific teaching strategy is suggested for the analysed concept.

Footnotes -- Chapter IV

[1]It could be argued that both characteristic moves relate the concept to another concept (i.e., "Watch" to "Time" and "Watch" to "Sun movements"). However, a distinguishing feature is that "Time" as a concept only has abstract referents while the referent of the concept termed "Sun movements" is an observable event. Put another way, describing a concept by relating it to another concept having an observable referent (i.e., one that could be in the person's experience) is a way of providing experiental reference for the former concept.

CHAPTER V

THEORETICAL AND PRACTICAL PROBLEMS FOR FURTHER STUDY

5.00 Introduction

Arising from the study are a number of problems ranging from questions about theory to questions about classroom practice, deserving further investigation. The problems were delineated in Phase IV of the study and are displayed in the present Chapter. The difficulties are viewed as ranging along a hypothetical continuum from theoretical problems at one end, to more practical problems at the other. Since the methodology developed for the study is, to a large extent, a bridge between a theoretical viewpoint of teaching built upon the conceptual framework provided by Smith and co-workers and some practical problems in science education (specifically concept teaching) the problems identified in the Chapter concern difficulties in connecting the two ends of the hypothetical theoretical-practical continuum. For the sake of order and clarity of presentation the problems are presented starting with the theoretical and proceeding to the practical.

5.10 The Theoretical Framework -- Problems Concerning Plays

As mentioned in a preceding section, the initial intent of the study was to use both the move and play categories for characterizing actual teaching strategies. However, major difficulties arose concerning

plays and consequently the play aspect of the theoretical framework was not employed. It may be of help for those wishing to employ the theoretical framework to take cognizance of these difficulties. The realization that these difficulties are present in the utilization of the framework may stimulate additional clarification or even further developmental work on the framework.

At the outset of the study it seemed to the writer that the play concept was sufficiently complete to warrant an attempt at utilizing the play categorizations. It became apparent during Phase II of the study, however, that some difficulties would have to be resolved first. According to Coombs, the delineation of plays is still not complete (Professor J. Coombs, personal communication).

The difficulties encountered in using plays developed from certain misconceptions about the nature of the relationship between moves, rule-formulations, plays and teaching functions. Moves are distinguished by the different sorts of information provided and rule-formulations are related to moves in that the information contained in each move implies a rule. Thus, the relationship between moves and rule-formulations was seen as a logical connection. One misconception was that plays provide information in addition to the information contained in the constituent moves. Another misconception was that plays, while composed of logically interconnected moves, were misconstrued as being logically connected to teaching functions when, in fact, plays should have been seen as being empirically connected to them.

According to Coombs (personal communication) plays do not provide information beyond the constituent moves. The concept play has to do with the way in which one introduces moves. For example, a particular play may be more effective than another in terms of teaching function, based on empirical fact, for producing understanding of a concept. Teaching functions are attempts to describe what has been effective in producing understanding of the concept. It may be possible for a teaching strategy (i.e. a pattern of moves and plays) to be complete, in that all necessary information needed to understand the concept has been presented, and yet, not produce an understanding of the concept. Stated another way, the strategy may not fulfill any of the three teaching functions. Thus, the connection between plays and teaching functions is empirical and not logical as was originally conceived by the writer.

A consequence of these misconceptions was the attempt to use plays for deducing rule-formulations in addition to those determined from the moves. Another result was that the writer tried to evaluate, on logical grounds, which plays should or should not have been performed in terms of teaching functions. Evaluation of plays in relationship to teaching functions would require further study of the empirical connections between plays and teaching functions. Since relationships of this kind have not been identified as yet, further consideration of plays in this light was abandoned as being beyond the scope of the present study. The problem of determining empirical relationships bet-

ween plays and actual learnings is offered as an important area for further investigation.

In addition to the theoretical difficulties with plays as pointed out above, a practical difficulty was encountered in the classification of moves into plays. None of the teaching strategies analysed seemed to fit the play categories described by Coombs (Thesis Section 2.25). A considerable number of the moves identified in the ventures were of the "case characterization" type, and therefore it was not possible to characterize these moves into plays because no plays employing these moves were identified.

5.20 The Theoretical Framework -- Problems Concerning Conceptual Ventures

The problem with conceptual ventures, as specified in the theoretical framework, is that they are too restrictive. Evaluation of a particular case of concept teaching should include all the relevant activities engaged in by teachers and students as they deal with the content of instruction, not just what was said in classroom discourse. Recalling Smith and co-workers' (Smith et al, 1967, p. 1) description of "strategies" as "the control of the subject matter of instruction" one realizes that classroom discourse is a major means of controlling subject matter. However, the framework should be extended to other controls of subject matter (i.e., written material -- textbooks) in order to give a more complete description of teaching behaviour. If the theoretical framework could be extended to include the written, as

well as spoken words, utilization of the framework to meet problems of teaching concepts, as taught in the classroom would be enhanced considerably.

One way of extending the framework would be to analyse textbooks and other written material using the moves for conceptual ventures. Three problems are foreseen; first, the relationship between written and oral activity as they pertain to classifying a conceptual venture would need clarification. Second, additional move categories for written material might also be required. And third, categorizations of other concrete operations in teaching such as demonstrations, textbook illustrations, and films might also be needed. The result of these extensions of the theoretical framework should be a more complete description of "the behaviour of teachers as they deal with students and the content of instruction" (Smith et al, 1967, p. 3).

5.30 Problems Concerning The Teaching Of Concepts

Nuthall in a study involving alternative strategies for teaching concepts and the resultant learnings, identifies an important problem in concept teaching. Nuthall (1968) points out that it may be difficult to separate the teaching strategy from the kind of concept being taught. It may well be that each concept to be taught requires its own particular teaching strategy. Analysing teaching strategies with respect to the denotative meaning of a concept (describing the physical features of a referent; Nunnally, 1967, p. 540) was accomplished

by Anderson (1968). Anderson described the denotative meaning of concepts in terms of the "ease-of-pointing" to features of the referent and the "number of pointings" necessary to describe the concept (i.e., point-at-ability of a concept; Anderson, 1968, p. 60). Taking Anderson's approach to the problem of analysing the kinds of concepts to be taught and combining it with the approach taken in the present study -- as delineated in Table 2 -- may be one way of viewing the difficulty posed by Nuthall.

The following is an illustration of some of the possibilities in using the combined approach: Considering the concept termed "Mass", as described by the rule-formulations listed in Table 11, one might still have difficulties in pointing to particular instances where the concept term "Mass" could be used. Yet, given an instance, one could say whether the term "Mass" was used properly in the instance or not. The distinguishing feature between the two situations is that for the first situation one is asked to "point-at" an instance, while in the second situation an instance is "pointed-out" and one must indicate whether the term "Mass" applies or not. Now, if the same two situations are considered for the concept termed "Wave Superposition" it would appear more likely that the rule-formulations for this concept (Table 11) are adequate for one to apply the concept term correctly in both situations. The difference between the concepts in these two situations lies in their "point-at-ability" -- the concept termed "Wave Superposition" seems easier to "point-at" than the concept termed "Mass".

The teaching strategies employed, differ for each concept. Table 12 summarizes the types of moves actually employed for each. Note that approximately the same number of moves were involved for the concepts when the teaching functions were to "provide relational meaning" or "experiential reference", and that more than twice the number of moves were used in providing context for the concept termed "Mass" when compared with "Wave Superposition". Keeping in mind the "point-at-ability", of the two concepts, "Mass" being more difficult to "point-at" than "Wave Superposition", the different functions to be accomplished in teaching these concepts should be considered. To illustrate, it may be advisable to provide additional context in teaching concepts difficult to "point-at" (less point-at-able) such as "Mass" than to more point-at-able concepts such as "Wave Superposition". It is suggested that the problem of devising teaching strategies for concept teaching be approached by considering the "functions to be accomplished in teaching a concept" in terms of the "point-at-ability" of a concept.

5.40 Classroom Practice -- A Handbook Of Teaching Strategies For Selected Concepts In Science

The methodology developed in this study could be used as a means of proposing specific teaching strategies for selected important science concepts. After empirically determining preferred teaching strategies, development could begin on a "Handbook of Teaching Strategies"

TABLE 12. Record Of Moves Used In Actual Teaching Strategies

Concept Term	Functions To Be Accomplished In Teaching The Concept																	
	Provide Relational Meaning							Provide Experiential Reference						Provide Content					
	(Move Number)*						Total Moves	(Move Number)*					Total Moves	(Move Number)*					Total Moves
	1	3	5	7	8	10		1	4	5	11	12		2	6	9	13	14	
Mass		2		1			3	2		5			7			4	1	2	7
Law in Physics	2		1		3		6	5		2	1		8		1			1	2
Electricity		2		1			3	1	2	3	1		7						-
Electric Field					2		2	1		3			4			3			3
Number of Field Lines							-			2			2			2			2
Feedback			1				1		1	2			3					2	2
Wave Superposition	1		1				2			5	2		7				3		3
Nuclear Binding Energy		1					1			3	1		4				2		2
Total . . .	3	5	3	2	5	-	18	9	3	25	5	-	42	-	1	9	8	3	21

*As described in Thesis Section 2.22

for selected science concepts. It could be possible to incorporate in the"Handbook" all the rule-formulations for a particular concept which seem to be necessary in order for a student at a given level of schooling to use the concept correctly. Identified with the rule-formulations for the concept could be preferred teaching strategies. In addition, suggested techniques for implementating the strategies could be included.

As an example of a way of using the methodology to begin developing a Handbook, consider the concept termed "Wave Superposition". Assuming that the teaching strategy for this concept as described in the thesis was the preferred teaching strategy, one might include the following in the Handbook: The segment of Tabel 11 describing rule-formulations for "Wave Superposition"; next to each rule-formulation the description of a move which could function to provide the necessary information for deducing the rule; a suggested ordering for the moves; and a proposed format or method presenting each move, i.e., straight lecture, discussion, demonstration, film, or any mixture of these methods. The contents of the "Handbook" could take the form of Programmed Instruction or as a programme in Computer Aided Instruction, because of an apparent resemblence between the logical structure of a computer program and conceptual ventures in the theoretical framework. For the university science instructor the "Handbook" might serve as a "Teaching Manual" for teaching those concepts which must be attained in order for a student to understand a particular paradigm.

5.50 Summary

The Chapter displays four problems which arise from the study and which deserve further investigation. The problems are viewed as ranging along a hypothetical continuum from theoretical at one end to practical at the other. In order of presentation, the problems begin with theoretical considerations and move toward practice. The problems identified were: The difficulties of employing the "play" concept of the theoretical framework, a suggested expansion of the conceptual venture idea to include written material with other discourse when analysing a teaching strategy; devising teaching strategies for concept teaching by considering the "functions to be accomplished in teaching a concept" in terms of the "point-at-ability" of a concept; and a suggestion for employing the methodology as a tool in devising "A Handbook of Teaching Strategies for Selected Science Concepts". These four problems describe a range of possibilities for further investigation arising from the work in this study.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.00 Summary

A fundamental assumption of the study is that teaching is a goal-directed activity. Viewed from one perspective, the major goal of science teaching is to display scientific paradigms. Scientific paradigms constitute what a "scientific community thinks it knows" (Kuhn, 1962, p. 139). Science concepts are an important part of scientific paradigms, and therefore, teaching science concepts becomes an essential aspect of teaching strategies used to display them. However, the teaching strategies used to teach science concepts are rarely, if ever, firmly based on systematized knowledge of teaching.

This study has explored the possibility of devising a method, based on a theoretical framework of teaching, which could be used to analyse and evaluate the teaching strategies employed in science courses to teach science concepts. The goal of the study has been to prepare a method to bridge the gap between theoretical knowledge of teaching and practical problems in science teaching.

The methodology developed in the study, was illustrated by applying it to actual teaching strategies used to teach concepts in a first-year university physics course. The development of the methodology required four phases: Identifying aspects of the theoretical framework potentially useful for analysing and evaluating the teaching of science concepts; characterizing records of actual teaching strategies; analysing

and evaluating actual teaching strategies for goodness-of-fit with ideal teaching strategies; and suggesting specific problems arising from the study requiring further investigation. Illustrations of each phase were presented and discussed.

The theoretical framework described in Chapter II is the result of Phase I. The methodology for the characterization of actual teaching strategies, developed in Phase II, entails the following procedures: Categorizing a conceptual venture into moves; organizing the information in the moves with respect to the functions they accomplish in teaching the concept; and displaying the organized information in summary form (Table 2). The methodology articulated further in Phase III resulted in four additional procedures. One procedure has to do with deducing rule-formulations for a concept seen as the "potential product" of an actual teaching strategy. Another procedure concerns deducing an ideal set of rule-formulations as the "intended product" of an ideal teaching strategy for the same concept. An evaluation procedure was developed in which the "intended product" and "potential product" were matched for similarity of information about a particular concept. A procedure was developed for devising teaching strategies specific for a particular concept, based upon the matching results. In Phase IV, four specific problems arising out of the development of the methodology and requiring further study were identified and described. The problems were envisioned as being along a hypothetical continuum from theoretical problems at one end, to practical problems at the other. The theoretical problems had

to do with specific difficulties in using the "play" and "conceptual venture" categorizations. At a somewhat less theoretical place in the continuum, specific problems were raised concerning concept teaching. At the practical end of the spectrum a problem of classroom practice was identified and a tentative solution suggested in the form of a "Handbook of Teaching Strategies for Selected Science Concepts".

6.10 Conclusions

A general conclusion of the study is that the theoretical framework used in the study appears to be potentially useful for analysing and evaluating certain aspects of classroom teaching. The venture and move categorizations of the framework proved tractable for analysing actual teaching strategies performed in a lecture-type teaching situation. Difficulty, however, is likely to be encountered if the play categorizations, at the present stage of development, are to be included in the methodology.

It should be emphasized that identifying the "intended product" of a teaching strategy is most difficult. If the methodology is employed by a teacher, then his personal determination of what he hopes to be the information presented in teaching would be the source for deducing rule-formulations representing the "intended product". On the other hand, if a person external to the teaching (i.e. an evaluator of the course or curriculum designer) were to employ the methodology some clear statement of the necessary and sufficient rule-formulations needed to

understand the concept would be required as the "intended product". The rules might be otained by requesting a group of experts in the subject matter area to indicate what information must be presented, in a teaching strategy or available to the students, for the students at a given level of schooling to understand the concept.

Classifying and organizing the information introduced by the various moves of a venture in terms of the functions to be accomplished in teaching a concept, appears useful not only for deducing rule-formulations for the concept embodied in a teaching venture, but also for evaluation purposes by identifying which function probably was not accomplished because appropriate moves were not made, or because the moves made were defective in some way.

Tabulations of the information introduced about a concept in the form of moves made in accomplishing the teaching functions can also be used to suggest teaching strategies that may, on logical grounds, be more effective than others. It was pointed out in the study, that concepts appear to differ in "point-at-ability" and that it may be advisable to consider devising teaching strategies with this aspect of concept teaching in mind. In addition, in cases, for example, where the concepts are hard to define because of difficulty in accomplishing the "experiential reference" function, it is suggested that additional moves providing "relational meaning" and "contextual information", be included in the teaching strategy to be devised. Although the methodology developed does not suggest a "best" strategy for any particular

concept, a problem for experimental study, it does suggest at least some considerations for devising teaching strategies for a concept.

The results of analysing conceptual ventures as demonstrated in the study are seen as potentially useful information to the teacher. In particular, a display of the rule-formulations for a concept deduced by this procedure, constituting both the "potential product" and the "intended product" of concept teaching is seen as a useful check for the instructor on how congruent his teaching was with his intents. Information about congruency of intents with teaching acts may suggest additional actions which need to be taken for improving teaching performance and identifying possible sources of difficulty students may be having in learning a concept. Further experimental study is needed to determine what the effects are on student learning of different kinds of teaching strategies and the degree of accomplishment of the functions of a particular teaching strategy.

Although the methodology developed was only applied to concept teaching, it would appear to be generalizable to other kinds of teaching as well. For example, in science teaching there is considerable concern with causal ventures in which cause-effect relations are taught. Concept and causal ventures, along with six other common classroom teaching ventures are provided for in the theoretical framework used in the study and should therefore make the methodology applicable in these teaching situations.

Finally, within the limitations specified in Chapter I of the

study, the methodology developed is seen as providing a possible way of linking an important theoretical view of teaching to classroom practice and, in so doing, providing a basis for future experimental investigation.

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APPENDICES

APPENDIX A

Conceptual Venture Presenting the Term "Wave Superposition"

A (5) This is a wave travelling but now let's find out how we could find about the wave length of this wave.

We could do it in the following way. We could have a wave travelling in one direction. The wave will be deflected at the other end -- will travel backwards towards me; and the two waves, the one wave travelling in this direction and the other wave travelling backwards will then superimpose.

B (11) Let's do this, and the pattern I get with a frequency just looks like a wave, but it doesn't run. It's standing. So this is what we call a standing wave.

C (12) Let's do it again with a different frequency. Let's try to make another standing wave. I'll take a higher frequency -- (pause) --. This is a standing wave.

D (13) Now let's try to understand how these standing waves come about. To understand this we have the first -- and essential principle. Have to remember...for most of you it's something you already did in school. We have to remember the principle of superposition of waves. So what we are setting out to do is, we are looking for experimental proofs of the wave nature of electromagnetic radiation -- (pause) -- .

E (1) And to do this we will make use of the principle of superposition. -- (pause) --. We could phrase it as follows. When two

waves pass the same point at the same time the waves at this point always superimpose. Just let's write this down like this, and then we will discuss what it means. -- (pause) --.

F (5) The meaning of this is as follows. Let's say we have one wave on this string. For instance, the wave I generated by moving my hand. And we have another travelling along the string. In this case the wave is travelling the other direction along this string. And this generated by reflection of the primary wave at the wall. Then, these two waves add up.

This means, for instance, if at this point we have a deflection upwards by the wave coming from this direction and upwards at the same time...by the way, from this direction we will get twice the amplitude, twice the deflection in this point.

G (5) Whereas, if the wave in this direction, for instance, upwards and the wave coming from the other direction would be downwards, then those two, if they have the same amplitude in this point, these two would cancel out. In this way the waves superimpose.

H (5) So to find the resultant wave pattern simply add up the wave pattern of the one wave and the wave pattern of the other wave and you get the resultant wave. Is this clear? That's called superimposed waves.

I (13) Now, I have to add a notice of caution for mechanical waves. This only holds for small amplitudes. When the amplitudes are large it

doesn't hold any more. But with electromagnetic waves this always holds.

J (5) Now, let's try, on these grounds, to understand the standing waves we saw just now. Let's look at this primitive machine I've got here. This is simply a wire wound around another wire. And when I turn the crank here this looks like a wave moving. It's rather a shaky machine, but anyway it works. So this symbolizes a wave travelling toward the left. Now we have another wire of this kind and this wire is bent such that the wave is coming the other way. Now if we were going to superimpose those two waves, we would just be in the situation as we were with the rubber string. One wave travelling in one direction, the other wave travelling the other direction, and both waves being sine waves. So let's just look at the situation point by point, and let's see how these two waves add up. -- (pause) --. I drew a line. Let's assume these two waves are travelling along the same string. So the line, the intersection of the line with this wave are the same point on the string actually. We are superimposing those two waves. We have them side by side just to compare. And let's see what will happen. Now you will see that the wire in the centre between those just is bent that way, that it looks like a superposition of those two waves. At least it should.

K (13) Now you see at this moment the upper wave and the lower are just ending their amplitudes and therefore the result is a deflection of higher amplitude. Now, at this moment both of them are

zero or almost counteracting. They are not quite properly bent I see. So they cancel out at this moment. Now both of them have negative amplitude. They add up that way that we have a negative deflection downwards. And so these two waves let's say here, for instance, then you will notice that the upper wave and the lower wave which are models for the wave travelling on the same string are always opposite, so they will cancel out. The upper wave is positive now, the lower wave is negative, cancelling. Both are zero. The upper is negative; the lower is positive; they are cancelling out. And therefore the superposition of those two waves in this point doesn't give a deflection all the time. Whereas the superposition of the waves in this point gives a maximum oscillation. And that is exactly what we saw when we saw the waves on the string. I produced a sine wave travelling the other direction. They superimpose in such a way that there are places of maximum oscillation and that there are places with no oscillation at all.

L (5) That's low frequency wave. We have one point which doesn't move at all. That's called a node. That doesn't move at all. Now let's take a higher frequency. It's still low frequency. Let's damp this down first. Now we have several nodes. Because I produced a since wave travelling in direction towards the wall and the sine wave was travelling back and those two were superimposing.

APPENDIX B

Criteria for Identifying Ventures

I. Definitions relevant to the concept of a venture.

1. The verbal behaviour occurring during a class period is called the total discourse.

2. An utterance is the complete verbal behaviour of one person at one point in the total discourse.

3. An episode is a unit of discourse involving a verbal exchange between at least two persons and focusing on a single point or item. It always contains more than one utterance.

4. A venture is a unit of discourse consisting of a set of utterances dealing with a single topic and having one overarching objective. It contains fewer utterances than the total discourse.

II. Criteria for Identifying a Venture.

1. The beginning of a venture is identified by one or more of the following:

   1.1 An utterance or part of an utterance containing an explicit indication (announcement or proposal), usually by the teacher, that a particular topic is to be considered. Such an announcement is usually followed by a question which initiates discussion of the proposed topic or by an invitation to speak on the topic.

   1.2 An utterance not explicitly indicating that a particular topic is to be taken up, but containing a question or statement that makes a marked change in the course of the discussion.

   1.3 An utterance containing a question or statement that initiates a discussion characterized by a new overarching objective.

2. Qualifications.

   2.1 When a venture includes one or more utterances containing a story, poem, student report, etc., or parts of such works or reports, new ventures may be identified in the subsequent discussion by criteria 1.1, 1.2, or 1.3 although the discussion continues to be about the particular story, poem, etc.

2.2 When a set of utterances concerns a number of mathematical problems, grammatical exercises or other examples and instances illustrating a single general principle (a rule of usage, a formula, a type of proof), these utterances together with any discussion of the general principle or further discussion of the instances shall count as a single venture.

2.3 When an utterance or set of utterances announces two or more topics to be taken up, the discussion of each topic counts as a venture, provided that each one is discussed independently rather than concurrently, provided that the discussions of the topics together do not form a topic unit having a single overarching objective. Discussions of the "pro" and "con", the "old and "new," and other such bifurcations of the topic shall not count as separate ventures.

3. Exceptions.

3.1 If an utterance contains an explicit indication (announcement or proposal) that a particular topic is to be considered but another topic is discussed instead of the one announced, the utterance in which the topic is announced does not count as the beginning of a new venture. Such utterances are to be labeled 'misfires' and are not to count as part of any venture.

3.2 An utterance or set of utterances occurring within the discussion of a topic but wholly unrelated to the topic is not to be counted as the beginning of a new venture. Rather it is to be marked off from the venture and labelled 'disruption'.

3.3 An utterance or set of utterances containing a statement of the general subject with which class discussion is to be concerned for an entire period or longer, or statements of assignments, school announcements, etc., counts as an orienting statement and is not to be considered as part of any venture.

3.4 An utterance or set of utterances occurring within the discussion of a topic but only loosely related to the topic is to be counted neither as the beginning of a new venture nor as a disruption. It is to be counted rather as part of the venture within which it occurs.

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in page numbering.

4. The end of a venture is marked by no special cues. The termination of a venture is signaled only by the beginning of a new venture or by the occurrence of an orienting statement.

5. The duration of a venture is limited by the following considerations:

   5.1 A venture always contains fewer utterances than the total discourse.

   5.2 Ventures generally contain more than one episode. A venture is only coextensive with an episode if it is not possible to legitimately consider the episode as part of the discussion of a more inclusive topic having a single overarching content objective.

III The procedural rules governing the use of these criteria are as follows:

1. Read the entire transcript through without attempting to apply the criteria. Get a general idea of the sorts of topics the lesson is divided into, the way in which the teacher groups things for the sake of discussion.

2. Read the transcript through again. This time mark off ventures using all the criteria except 1.3. If the transcript is particularly difficult it may be advisable to mark the readily identifiable ventures first and then return to the hard portions.

3. Use criterion 1.3 to correct the markings made in (2) above. Remember, every venture must have a single overarching objective.

4. While length is not a criterion of a venture, length in excess of three or four pages of transcript does serve as a warning signal, indicating that the start of a new venture may have been missed.

APPENDIX C

Criteria and Instructions for Classifying Ventures

I Definitions

1. A venture is a unit of discourse consisting of a set of utterances dealing with a single topic and having a primary cognitive meaning.

2. The cognitive meaning of a venture is the sense or import of the venture taken as a whole. A venture typically contains one or more submeanings or points which contribute to or make up the venture's primary meaning, and in some cases it contains irrelevant or peripheral materials. These sub-points and peripheral materials are to be distinguished from the venture's primary cognitive import.

   2.1 The cognitive meaning of a venture is not to be confused with the purpose or objective of the teacher. Nor is it to be mistaken for either the outcome of instruction or student learning. The cognitive meaning of a venture is derived from the discourse that makes up the venture and not from efforts to divine the intent or purpose of the teacher or the effects of the venture upon students.

Conceptual Venture

1. The primary cognitive import of this type of venture is that of disclosing the conditions or criteria governing the use of a term. A term may be a single word such as "imperialism" or an expression of two or more words such as "coefficient of expansion". A conceptual venture may be identified by one or more of the following criteria:

   2.1 An X is mentioned and the class discussion is primarily directed to such questions as: What is X? What does X mean? What do we mean by X? How can we tell when something is an X?

   2.2 Something is named or referred to, and the class discussion is mainly devoted to describing its characteristics, functions, uses, or parts.

   2.3 Something is named or referred to, and the class discussion is primarily devoted to mentioning or considering examples of it.

INSTRUCTIONS FOR CLASSIFYING VENTURES

1. Each venture can be classified by its cognitive objective into one of the following categories: causal, conceptual, evaluative, particular, interpretative, procedural, reason, and rule ventures.

2. Read the entire venture for the sense of it as a whole. Then read it again and try to formulate the question with which the venture deals. For example, does it deal with the cause of something? Does it attempt to get at the reasons for an act, decision, or whatever? By using the criteria given for each category, classify the venture into the category which it fits best.

3. No venture may have more than one objective.

4. If a venture is very difficult to classify, put it aside. When the easier cases have been grouped, return to the more difficult ones.

5. In some cases it is difficult to tell whether a venture belongs in the reason or in the rule category. Where there are a number of specific decisions or actions falling in a particular category and all regulated by the same rule or justified by the same reason (e.g., students are asked to decide which words in a number of sentences are verbs), the venture is to be called a rule venture. If the specific decision or action is justifiable by different reasons (e.g., students are asked why Mr. X went into the house), the venture is to be classified as a reason venture.

6. It is sometimes difficult to decide whether or not to put a venture in the evaluative category, although it contains a number of value judgments about different objects, ideas, etc. As a rule, when a venture centres in the evaluation of a single object, event, and the like, it is to be classed in the evaluative category. If the venture contains a number of evaluations about a number of different objects, events, reasons, and so forth, along with other materials, it does not belong among the evaluative ventures.

7. Particular ventures are sometimes difficult to distinguish from other sorts of ventures because all ventures are informative, and many provide information about particular objects or persons or entities. However, when information is given concerning the classificatory characteristics of an object or entity, and when information is given in response to some dominant logical enterprise such as evaluation, explanation, etc., the venture should not be classified as a particular venture.

APPENDIX D

Example of Pre-Lecture Analysis Form

Lecture section A

Lecture date March 3rd, 1970

Number of sheets for this transaction 1 of 1

TRANSACTION: WAVE SUPERIMPOSE

PURPOSE: STATE IMPORTANT WAVE PROPERTY AND LIMITATIONS

APPROPRIATE TAXONOMY POSITION: 1.22 COGN. AFFECTIVE.
(Cognitive domain, or if applicable Affective domain)

METHOD OF PRESENTATION: (please circle appropriate method(s))

/Lecture/	Demonstration
Film	Token demonstration
Slides	Other (specify) _____

IMPORTANCE: For each group of students how important is this purpose of this transaction? Please use a five point scale with 5= very important, and 1 = unimportant, Use a questionmark (?) for not sure.

		all	1st	2nd	up pass	low pass
Cognitive	for "scientific literacy"	4				
	for reinforcing a concept	1				
	for technical purpose in course	3				
	for technical purpose in lecture	5				
Attitude	for physics in general					
	for this course					
	for this lecture					

EXPECTED STUDENT INTEREST: (please circle the appropriate level for each)

Students							
1st class	low 1	2	3	4	5 high		
2nd class	1	2	3	4	5		
Upper Pass	1	2	3	4	5		
Lower pass	1	2	3	4	5		
Probable fail	1	2	3	4	5		

EXPECTED STUDENT PREPARATION:

Previous lecture(s): February 25th, 1970 (please indicate date)

Text material: --

Lab. Experience: Acoustic Experiment (For those who did it)

Other (specify): Experience with water waves

EVIDENCE OF STUDENT UNDERSTANDING WILL BE OBTAINED: (circle appropriate)

/Do not know/	Attitude test	1st midterm	Christmas exam
Not at all	Lab. reports	2nd midterm	Final exam
	Home assign.	Other (specify) _____	