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ROBERT JOHN WHITAKER

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TEACHING PRACTICES IN INTRODUCTORY PHYSICS COURSES IN

SELECTED OKLAHOMA COLLEGES

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TEACHING PRACTICES IN INTRODUCTORY PHYSICS COURSES IN SELECTED OKLAHOMA COLLEGES

CHAPTER I

BACKGROUND AND NEED FOR THE STUDY

For a number of years college teaching has undergone much criticism and discussion. Debates, not always at an intellectual level, have taken place between and among students, teachers, and administrators. This discussion has often dealt with the quality of the teaching process and the relevance of the academic content.

This concern for relevance and quality does not seem to be related to any particular subject area. Students seeking advanced degrees in most subjects are finding an increasingly difficult time in finding employment upon graduation.[1] Science and engineering graduates, who for so long were at a premium on the job market, are now faced with seeking new kinds of employment outside of their specialties.[2]

The growing surplus of Ph.D.'s has led to a number of suggestions directed at reducing graduate enrollments. Among the proposed suggestions

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[1]For a discussion of the problems posed by the increased numbers of Ph.D.'s see Dael Wolfe and Charles V. Kidd, "The Future Market for Ph.D.'s," Science, CLXXIII (August 27, 1971), 784-793.

[2]The activities of seven physicists who are working in fields outside of physics teaching or research are described by Marian S. Rothenberg, "Physicists with Unusual Careers," Physics Today, XXIII (May, 1970), 23-30.

is a reduction of the number of undergraduate majors. This proposal, as it would apply to physics majors, is strongly criticized by Kenneth W. Ford of the American Association of Physics Teachers. Ford notes: "Physics now accounts for less than 0.7% of all bachelor's degrees, far too small a fraction."[1] He offers the view that a study of physics has value for many students who will not pursue physics as a career. He goes on to state:

> We have abdicated to our colleagues in other departments the job of providing an interesting program for students who want to major in a subject without a professional goal in that subject. Given the typical pattern of our undergraduate instruction, it is in fact logical--however regrettable--to cut down the Ph.D. production rate by discouraging undergraduate majors. Yet we should be going in exactly the opposite direction, rising to our responsibility to educate people. . . . We need interesting and meaningful major programs for future teachers, physicians, businessmen, authors. . . .[2]

That a study of physics has value for students interested in other fields is not a point that would be denied by those who teach it. The fact remains, however, that physics enrollments have been on the decline for some time. One might speculate on the causes of this decline, but little positive information is available to support such conjectures. A need exists to establish a base which might provide some clues toward changing the present trends in enrollment. A starting place for establishing this base is the introductory college physics course.

Statement of the Problem

This research proposes to examine the teaching practices that the teachers of beginning college physics display in teaching the introduc-

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[1] Kenneth W. Ford, "Physics for People," Physics Today, XXIV (September, 1971), 9.

[2] Ibid.

tory college physics course. More specifically this research will seek information to answer the following questions. The questions are listed in the researcher's order of importance.

1. What goals do college teachers espouse as being the most important in the beginning course?

2. What objectives do these teachers state as being the most important in the teaching of a specific lesson?

3. How do the goals of the individual instructor compare with those expressed by the various committees and conferences stated on pp. 9-10?

4. What methods of instruction do instructors of beginning physics employ?

5. What types of questions are asked by the teacher in teaching the introductory course?

6. What is the purpose of the questions a teacher asks in terms of expected response?

7. How do the types of questions asked compare with the expressed objectives of the lesson and the course?

8. What is the nature of the class assignments?

9. What textbooks and other supplemental teaching materials are used?

Significance

The introductory physics course is required by a large percentage of the college student body. It is an admission requirement for 97 of 101 American medical schools[1] and for all 51 American dental schools.[2] In addition, physics is a basic course for engineering and many other

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[1] Medical School Admission Requirements (19th ed.; Evanston, Ill.: Association of American Medical Colleges, 1968-69), p.3.

[2] Admission Requirements of American Dental Schools: 1969-70 (Chicago, Ill.: American Association of Dental Schools, 1968), p. 13.

branches of science. Science requirements for liberal arts students are often met with a course that includes some physics or by one that is all physics. Elementary school teachers at the University of Oklahoma, for example, are required to take a one semester course in physics.

At the same time recent surveys reveal that the enrollment in college physics is on the decline.[1] Arnold Strassenburg of the American Institute of Physics has expressed concern that elementary teachers and other non-science students who will become voters and political leaders are not learning the role that science plays in out lives. Indeed, he expresses concern that many students do not ". . .find physics, as we present it in the classroom today, relevant to the solution of world problems. In fact, I fear that quite the opposite is often true."[2]

Crane expresses the same concern regarding the physics course offered to the non-science student. He states that this course ". . . is the main channel at the college level for communicating physics to the educated citizenry, and we are acutely aware, in these days, that the group includes our lawmakers. We need to have them understand what physics is about, as much as they need physics in their business."[3] He goes on to express the opinion that introductory physics is ". . .one of the best vehicles for training people to be fast on their intellectual feet but that we do not take advantage of the potential."[4]

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[1]A. A. Strassenburg, "Will Physics Become Obsolete?" American Journal of Physics, XXXVI (June, 1968), 520-523.

[2]Ibid., p. 524.

[3]H. R. Crane, "Students Do Not Think Physics Is 'Relevant.' What Can We Do About It?" American Journal of Physics, XXXVI (December, 1968), 1138.

[4]Ibid., p. 1142.

These are strong indictments against the teaching of college physics as it is now done. Is teaching in the ways described predominate? Before the answers to these criticisms can be known, more must be known of what the instructor does in the classroom. More information must be available about the goals the individual instructor expresses for the introductory course and whether he meets these goals in his teaching. There is only one procedure which can be used to secure that information--go into the college physics classroom and observe teaching and talk with instructors about their purposes for and attitudes about teaching physics.

History of the Problem

The rise of the American universities in the last quarter of the 19th century saw many changes in college teaching.[1] Among these changes was an increase of specialization in the different subject areas. With this specialization came an increase in the number of courses taught in a specific field and an emphasis on research. These changes also brought forth a new degree of professionalization within subject areas. Physics in the universities also shared in these changes. The role of research was emphasized as it had never been before. The growth of professionalism among physicists led to the founding of the American Physical Society (APS) in 1899. Its primary goal was ". . .to encourage and promote research in universities. . . ."[2]

The founding of the American Physical Society helped to raise the professional status of physics in the universities, but that rise was not

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[1]A more thorough survey of the development of teaching practices in American colleges in given in Appendix B.

[2]The American Association of Physics Teachers, Organization and Activities; History; Constitution and Bylaws; Directory of Members as of October, 1966, p.7.

without its problems. The interests of university physicists became more directed toward research than toward teaching. Papers dealing with the teaching aspects of physics were systematically excluded from meetings and from the APS official journal, The Physical Review. This situation did not remain unchallenged long. Woodhull, writing in 1910 observed: ". . .it is difficult to find a college instructor, educated within the last ten or fifteen years, who makes it his chief interest to teach or who likes to acknowledge that it is his chief business."[1] Similar criticism was voiced by Frayne in 1928.

> The best physicists in our Colleges are so engrossed in research in the new physics that they pay little attention to teaching the undergraduate student. There has been practically no research in methods or technique for class-room or laboratory teaching. The general attitude has been one of indifference and even hostility to any interference with traditional procedure. The result is that in 1928 we are teaching physics very much as it was taught in 1900 while the subject matter in the meantime has been almost entirely rewritten.[2]

Over the years an increasing need was felt for the formation of an organization devoted to the teaching of college physics. This need reached fruition in 1930 with the adoption of a constitution for the American Association of Physics Teachers (AAPT). The official journal of the new organization, The American Physics Teacher, appeared in February, 1933, as a quarterly publication "devoted to the instructional and cultural aspects of physical science." In 1940 the journal's name was changed to the American Journal of Physics. The journal has grown from a quarterly publication of 132 pages per year in 1933 to a monthly

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[1]John F. Woodhull, "What Specialization Has Done for Physics Teaching," Science, (N.S.) XXXI (May 13, 1910), 729.

[2]John G. Frayne, "The Plight of College Physics," School Science and Mathematics, XXVIII (April, 1928), 345.

publication of 1,320 pages in 1969. A second journal, The Physics Teacher, appeared in 1963. Its contents are devoted more closely to the teaching aspects of physics.

The college physics teaching profession has devoted much time and effort toward the introductory course in physics. In 1933 the AAPT, in cooperation with the Cooperative Test Service of the American Council on Education, inaugurated the College Physics Testing Program. Through this program standardized tests were developed and a new series of tests was made available each year during a five year period. Between 252 to 355 colleges participated in this program during its period of operation. This testing program provided a means of studying students in introductory physics on a national scale and served, at least among those participating instructors, as a means of calling attention to certain aspects of the teaching of college physics.[1]

In 1934 Richard M. Sutton was appointed by the American Association of Physics Teachers to serve as editor-in-chief of a manual on demonstration experiments. This effort was completed in 1938 with the publication of Demonstration Experiments in Physics.[2] A second Association sponsored reference, The Lloyd William Taylor Manual of Advanced Undergraduate Experiments in Physics,[3] appeared in 1958.

The American Association of Physics Teachers, with financial support

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[1]The Committee on Tests of the American Association of Physics Teachers, "Measuring the Results of Instruction in College Physics," American Journal of Physics, VIII (June, 1940), 173-180.

[2]Richard M. Sutton, ed., Demonstration Experiments in Physics (New York: McGraw-Hill Book Company, 1938).

[3]T. B. Brown, ed., The Lloyd William Taylor Manual of Advanced Undergraduate Experiments in Physics (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1958).

of the National Science Foundation, has also sponsored a series of conferences devoted to different aspects of introductory physics. Beginning in 1954, these conferences have devoted attention to the training of college laboratory assistants; improving the quality and effectiveness of introductory college physics; laboratory instruction in general physics; lecture demonstrations; curricula for undergraduate physics majors; and physics for nonscience majors.[1] Each of these conferences, in its own way, gives evidence of the importance of the beginning course, whether it is designed as a first course for a physics major or as a terminal course for a liberal arts student.

In 1960 the Commission on College Physics was established as a cooperative effort of physics departments, professional organizations, and individuals. Through the Commission active support has been given to innovations in physics teaching. Such Commission-supported beginning courses as the Berkeley Physics Course,[2] the Feynman physics lectures,[3] and

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[1] These conferences were held at: Northwestern University, June 25-26, 1954; Carleton College, September 5-8, 1956, financed by a grant from the General Electric Company; The University of Connecticut, June 17-19, 1957; Wesleyan University, June 22-24, 1959; University of Denver, August 13 to September 2, 1961, and followed up by two conferences at the University of Michigan May 14-16 and on November 12-14, 1962; the University of Colorado, July 20-29, 1964.

[2] Charles Kittel, Walter D. Knight, and Malvin A. Ruderman, Berkeley Physics Course, Vol. I: Mechanics (McGraw-Hill Book Company, 1965). Edward M. Purcell, Berkeley Physics Course, Vol. II: Electricity and Magnetism (New York: McGraw-Hill Book Company, 1965). Frank S. Crawford, Jr., Berkeley Physics Course, Vol. III: Waves and Oscillations (McGraw-Hill Book Company, 19). Eyvind H. Wichmann, Berkeley Physics Course, Vol.IV : Quantum Physics (McGraw-Hill Book Company, 1970). F. Reif, Berkeley Physics Course, Vol. V: Statistical Physics (McGraw-Hill Book Company, 1965).

[3] Richard P. Feynman,Robert B. Leighton, and Mathew Sands, The Feynman Lectures on Physics, 3 vols. (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1963-1966).

Physical Science for Nonscience Students[1] have reached the commercial market. In addition the Commission has encouraged and sponsored the development of new apparatus, films, bibliographies devoted to specific physics topics, and low priced monographs suitable for the beginning college student. Dissemination of information about these activities has been by way of the Commission's Newsletter[2] and through such professional journals as the American Journal of Physics.

Student Goals for the Study of College Physics

The activities of the college teaching profession that have been devoted to the beginning course in physics reveal that considerable importance is given to this course. In attempting to examine the influence of these activities in the individual classroom, however, it is necessary to examine the goals which have been set forth by the profession for the study of physics.

In 1954 a committee of the American Institute of Physics, at the request of the American Society for Engineering Education, published a report that set forth a series of contributions that a study of physics should provide for the prospective engineer. The report stated that through a study of physics the student should:

(1) Develop a curiosity about the physical world.

(2) Learn the limitations of physical theories.

(3) Learn the value of mathematical expression in solving physical problems.

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[1]PSNS Project Staff, An Approach to Physical Science, (New York: John Wiley & Sons, Inc., 1969).

[2]Commission on College Physics, Department of Physics and Astronomy, University of Maryland, 4321 Hartwick Road, College Park, Maryland 20740.

(4) Appreciate the historical development of physical ideas.

(5) Appreciate the importance of precise methods of measurement.

(6) Learn the value of formulating objective judgements.

(7) Understand the basic concepts of physics.[1]

The conferences held at Carleton College and the University of Denver both endorsed the above goals as being suitable for physics majors and for other science students and non-science majors as well.[2,3] The Carleton Conference went on to emphasize the value of physics in developing certain skills. Through the study of physics the student may improve his ability to:

(1) Approach and solve new problems using verbal formulation, mathematical analysis, or experimental manipulation.

(2) Read and comprehend scientific writings at various levels of complexity.

(3) Express himself in clear, succinct, and precise statements, written or oral, qualitative or quantitative.[4]

Each conference also devoted a major effort to defining the content necessary to implement these goals. The conferees placed special emphasis on the need to reduce the encyclopedic coverage of many introductory courses. They further suggested that a certain limited number

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[1]"The Role of Physics in Engineering Education: The Report of a Committee of the American Institute of Physics," Physics Today, VIII (December, 1955), 17.

[2]"Improving the Quality and Effectiveness of Introductory Physics Courses," American Journal of Physics, XXV (October, 1957), 417. (Hereinafter referred to as the "Report of the Carleton Conference.")

[3]Byron E. Cohn, ed., Group Reports and Summaries of the Conferences on Curricula for Undergraduate Majors in Physics (Denver, Colo.: University of Denver, August, 1961), pp. II A 2; G 7.

[4]"Report of the Carleton Conference," p. 420.

of topics should receive fuller coverage at the expense of other, traditionally-established ones.[1]

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[1]Ibid., pp. 420-21.

CHAPTER II

RELATED RESEARCH

The literature devoted to the teaching aspects of higher education falls into three major categories. The first of these deals with the methods of instruction used--lecture, discussion, demonstrations, laboratory, and field trips. Second is those studies dealing with teacher effectiveness as demonstrated by student rating forms. And third is studies of the activities of the teacher in the classroom. This research reveals a wide variety of teaching problems that have received recognition as well as a wide range of approaches to their study.

A number of works devote attention to teaching methods. Cronkhite has edited a handbook of informative essays for the beginning college teacher.[1] Brown and Thornton have presented succinct outlines of the major teaching methods.[2] The advantages and disadvantages of such methods as formal lecture, informal lecture, group discussion, role playing, demonstrations, laboratory instruction, case study, and field trips are clearly summarized. These works, however, present statements of teaching ideals and not of actual performance.

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[1]Bernice Brown Cronkhite, ed., A Handbook for College Teachers: An Informal Guide (Cambridge, Mass.: Harvard University Press, 1950).

[2]James W. Brown and James W. Thornton, Jr., College Teaching: Perspectives and Guidelines (New York, San Francisco, Toronto, London: McGraw-Hill Book Company Inc., 1963), pp. 138-154.

McKeachie has conducted an extensive review of studies on college teaching. He notes in his introduction that ". . .in evaluating the effectiveness of college instruction we need to consider not only the accumulation of knowledge but also the development of problem-solving skills and of desirable attitudes."[1]

A large number of the studies summarized in his survey deal with different teaching methods. While the studies on teaching methods and those dealing specifically with instructor-centered and student-centered methods reported by McKeachie reveal much about the teaching process, it is still not clear from this survey that the precise behaviors of the different instructors were observed in detail.[2] What teaching styles, if any, actually separated teachers who employed these different methods?

The lecture demonstration is a widely used method in the teaching of science. Cunningham, in 1946, reviewed thirty-seven studies devoted to the question of lecture demonstrations versus individual laboratory methods in science teaching. His survey covered research on elementary, secondary, and college science teaching dating from 1912 to 1943. Of these studies only three were concerned with college teaching, and none was devoted to physics.[3]

The results of the research studies reviewed by Cunningham were not all in agreement. Of those studies that gave attention to immediate

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[1]W. J. McKeachie, "Procedures and Techniques of Teaching: A Survey of Experimental Studies," in The American College, ed., by Nevitt Sanford (New York, London, and Sydney: John Wiley & Sons, Inc., 1962), p. 313.

[2]*Ibid.*, p. 328

[3]Harry A. Cunningham, "Lecture Demonstration Versus Individual Laboratory Method in Science Teaching--A Summary," Science Education, XXX (March, 1946), 74.

recall or results, "Twenty gave results favoring demonstration method; six favored the individual laboratory method; and two said that there was no difference."[1] Those studies devoted to delayed results revealed that ". . .ten favored the demonstration method, eleven the individual laboratory method, and three reported no difference."[2]

In general the method judged to be superior was closely dependent upon the goals defined for the lesson. Cunningham concludes:

> Our decision, as to what to do in practice, is made easier when we realize that all of our laboratory teaching need not--should not--be done by one method. It is possible that we may be ignoring a whole continuous series of possibilities between these two extremes. In many cases it may be found best to use both methods in teaching a given topic or idea in science.[3]

Kruglak and Carlson have reported on a pilot study to compare the effectiveness of introductory college physics instruction by two methods. One group of students received instruction in a conventional physics laborabory situation. The second group observed the same experiments demonstrated by an instructor: the students did not manipulate the apparatus in any way. The researchers posed the null hypotheses: "No difference in learning outcomes appears between students who perform conventional laboratory experiments in elementary physics and students for whom the same experiments are demonstrated by the laboratory instructor."[4]

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[1]Ibid., p. 76.

[2]Ibid.

[3]Ibid., p. 79.

[4]Haym Kruglak and C. Raymond Carlson, "An Experimental Study in Elementary College Physics," in A University Looks at Its Program, ed. by Ruth E. Eckert and Robert J. Keller (Minneapolis, Minn.: The University of Minnesota Press, 1954), pp. 104-105.

After assuring themselves of the equivalence of control and experimental groups and the equivalence of other aspects of instruction, instructors were selected and assigned by coin toss to the two control and two experimental sections.[1] Possible differences between instructors were controlled by analysis of variance and analysis of covariance. The results of this study were as follows:

1. On tests dealing specifically with laboratory material the laboratory groups were found to be superior.
2. No differences were observed between the two groups on the theory test.
3. No differences were observed between the groups on the theory and laboratory written tests. However, the conventional laboratory group was superior on a long-item practical laboratory examination using laboratory apparatus.
4. The laboratory method was found to be superior on a short-item laboratory test. However, this difference disappeared when the effects of the pretest and previous physics grade were taken into account.[2]

The study by Kruglak and Carlson concentrates on the effectiveness of the transfer of information by two conventional teaching methods--demonstration and standard laboratory instruction. While the results of this study provided information regarding this one aspect of physics teaching, the attainment of various other goals such as expressed by the conferences on introductory physics were not examined.

Richardson and Renner report another study in which the performance

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[1] Ibid., p. 107.

[2] Ibid., p. 117.

of students taught by inquiry are compared to those taught from a conventional laboratory manual in beginning college chemistry.[1] Students during three different semesters were randomly assigned to experimental and control groups. Students in the control groups performed experiments from a commercially available laboratory manual, and students in the experimental group performed experiments on the same topic from material designed and written utilizing the inquiry approach to learning. These experiments were designed in such a way that no prior knowledge of chemistry by the students was necessary; they were experiments frequently encountered in commercially available laboratory manuals; and no experiment required more than two hours to complete. Statistical tests revealed that the average scores of the experimental group on the final laboratory examination were significantly better than the control group for all three semesters. Taking into account the results of twenty-one different tests which were given to both groups during the three semesters, the experimental group showed significantly higher achievement over the control group in 18 out of 21 tests. The researchers conclude:

> The data collected and its statistical interpretation justify the conclusion that in a variety of actual learning situations regardless of the control of the inherent variables, the inquiry method of learning as opposed to the conventional laboratory procedure resulted in significantly better performance, on the measures used, by the students using the inquiry method.[2]

The above studies and similar studies have measured the differences

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[1]Verlin Richardson and John W. Renner, "A Study of the Inquiry-Discovery Method of Laboratory Instruction," Journal of Chemical Education, XLVII (January, 1970), 77-79.

[2]Ibid., p.79

between two methods of instruction in terms of pre- and post-instruction student grades or test scores. The effect of the instructor is usually controlled by careful assignment to experimental and control groups and to statistical methods designed to eliminate or otherwise control the individual effects of different instructors. These studies, while valuable, still do not identify important individual differences that may occur among instructors.

Fred J. Kelly, reviewing research into college teaching in 1951, commented: "Extensive research is needed not only to identify the qualities which characterize a superior teacher, but also to improve the reliability of the instruments used to measure teaching effectiveness."[1] Kelley's remark is exemplary of how concerned persons have urged that research be done into the primary function of high education --teaching.

A major difficulty arises, however, when "superior" teachers and teaching "effectiveness" are discussed. These terms imply value judgements which, at best, can be highly subjective; what appears to be superior teaching to one observer may appear mediocre to another. One means that has been employed to evaluate teacher effectiveness is the teacher rating form. Allport reports the results of a pilot study in which five teachers were rated by what was termed expert observers and by their students. Curiously, rankings of the observers were the reverse of the students for the three best teachers in the study; i.e., characteristics criticized by the observers were taken as favorable by the students.[2]

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[1]Fred J. Kelly, "Recent Publications on College Teaching--A Brief Review," Higher Education, VII (June 1, 1951), 223.

[2]Gorden W. Allport, "How Shall We Evaluate Teaching," in A Handbook for College Teachers, ed. by Bernice Brown Cronkhite, pp. 42-52.

The foregoing may explain why a gap in understanding seems to exist at present between students and faculty.

Representative of student ratings of teachers is the report of studies at the University of Minnesota by Clark and Keller where the faculty of the College of Science, Literature, and the Arts were rated by almost 15,000 students in 380 classes. The survey instrument rated instructors on such characteristics as clarity of speaking, assignments, tolerence to the opinions of others, class preparation, examinations, and requiring original thinking. While these subjective ratings had certain value to the individual instructor in pointing out weak areas in his overall teaching, the categories were not ones that could be consistently replicated by a number of independent observers.[1]

A second problem arises in the use of rating forms. Do students evaluate a teacher in the same way that a teacher evaluates himself? Gowin and Payne have reported the results of a study which dealt with the teacher's self perception and his view of his students perception of him. Students evaluated a group of inexperienced college teachers on the teachers' classroom performance, and the teachers evaluated themselves. The students were also asked to predict how the teacher would rate his own performance; the teachers were asked to predict how the students would rate him.[2] In general the teacher's opinion of himself and the students' opinion of the teacher were not significantly different. However, the teachers tended to underate the students'

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[1]Kenneth E. Clark and Robert J. Keller, "Student Ratings of College Teaching,: in A University Looks at Its Program, ed. by Ruth E. Eckert and Robert J. Keller, pp. 200-212.

[2]D. Bob Gowin and Donald E. Payne, "Evaluating Instruction: Cross-Perceptions of College Students and Teachers," The School Review, LXX (Summer, 1962), 208-209.

opinions of their performance, and the students overestimated the teachers' opinion of themselves. The researchers observed that the teachers who assigned the lowest average class grades were the ones who believed the students saw them as unstimulating and were also the teachers who received the lowest average over-all ratings.[1] The authors concluded that ". . .the teacher responded to the perceptions he believed his students held of him rather than, as is usually assumed, to his self-perceptions."[2]

Gowin and Payne note that most evaluation forms stop with the students' perception of the teacher. The use of these forms assumes that students are able to recognize good teaching. Since the study showed that there was not high agreement between students and teachers on teaching effectiveness, then this assumption is not completely valid. The researchers concluded that a lack of communication seems to exist between the teacher and the student of what constitutes good teaching. Furthermore they also observed that ". . .rating forms are often inadequate instruments to identify differences in the teaching abilities of different teachers. The teachers were much more alike than different."[3] Thus a problem still remains in distinguishing the nature of the differences among teachers.

Several recent studies have concentrated on the teacher's behavior in the classroom. Among these studies, the theoretical work of Bloom and the Committee of College and University Examiners is highly impor-

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[1] *Ibid.*, pp. 214-215.

[2] *Ibid.*, p. 215.

[3] *Ibid.*, p. 218.

tant.[1] This work attempts to classify and define the intellectual goals that are held to be important in the literature of education. The intellectual goals classified by Bloom are knowledge, comprehension, application, analysis, synthesis and evaluation. With these goals in mind the teacher has a standard which he can use to direct the activities of his students toward their attainment. Bloom gives numerous examples of the classification of these goals in examination questions. Thus an examination of the actions of a teacher in the classroom can reveal the goals that the teacher has in mind. It may also reveal whether the teacher is actually attaining the goals which he has set out to accomplish.

This viewpoint is reinforced by Harris in his development of an observational guide for school supervisors. He states:

> The types of questions which teachers ask in discussions, in oral recitations, or on tests provide clues to the kind of learning that is being pursued in the classroom. Teachers who emphasize the superficial by asking questions which call only for regurgitation of memorized facts set a tone of expectations for pupils which tends to guide study and learning at the same level of superficiality. On the other hand, teachers who ask questions which require deeper levels of understanding set a tone for the same kind of study and learning.[2]

Massialas and Zevin have provided a detailed exploratory examination of inquiry teaching methods at the secondary school level.[3] Transcripts of classes in geography, sociology, biology, music, lit-

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[1]Benjamin S. Bloom, ed., Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain (New York: David McKay Company, Inc., 1956). (Hereinafter referred to as Bloom, Taxonomy.)

[2]Ben M. Harris, Supervisory Behavior in Education (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963, pp. 164-165.

[3]Byron G. Massialas and Jack Zevin, Creative Encounters in the Classroom: Teaching and Learning Through Discovery (New York, London, Sydney: John Wiley & Sons, Inc., 1967).

erature, archeology, English, and government provide a series of case studies of inquiry teaching. This report provides a clear description of the use of inquiry teaching at the secondary level. The approach employed by the authors in reporting these studies, however, makes it difficult if not impossible, to compare the teaching practices of one teacher with those of another. Indeed, the authors emphasize in their conclusion the need for further reproductions of actual classroom situations and the need for a systematic method of analyzing classroom discourse.[1]

The studies by Wilson, Porterfield, and Schmidt have examined the teaching practices of a number of elementary school teachers.[2] This research has been summarized by Renner and Stafford.[3] Basically these studies examined the types of questions asked by teachers ". . .who has been educated in inquiry-centered methods and materials for science instruction. . ."[4] and by other teachers who had not received this instruction. These three studies examined the effect of this instruction on the teaching of science, reading, and social studies. Each of the

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[1]Ibid., pp. 262-263

[2]John H. Wilson, "Differences Between the Inquiry-Discovery and the Traditional Approaches to Teaching Science in Elementary Schools" (unpublished Ed. D. dissertation, The University of Oklahoma, 1967); Denzil Ray Porterfield, "Influence of Preparation in Science Curriculum Improvement Study on Questioning Behavior of Selected Second and Fourth Grade Reading Teachers" (unpublished Ed. D. dissertation, The University of Oklahoma, 1969); Frederick B. Schmidt, "The Influence of a Summer Institute in Inquiry-Centered Education Upon the Teaching Strategies of Elementary Teachers in Two Disciplines" (unpublished Ph. D. dissertation, The University of Oklahoma, 1969).

[3]John W. Renner and Donald G. Stafford, "Inquiry, Children, and Teachers," The Science Teacher, XXXVII (April, 1970), 55-57.

[4]Ibid., p. 56

studies revealed that the teachers who had received this special education asked, on the average, more questions and questions which required greater use of the students' higher cognitive powers--analysis and synthesis--than those teachers who had not received this education.

Another study has been reported by Fischler and Zimmer which raises the problem associated with the grouping of students in junior high school science classes.[1] The problem that arises in such grouping is whether different teaching methods actually take place in each of the different groups. "The teachers say that they do change their methods for different groups; in fact, they are convinced that they do. However, the only way to find out is to observe their behavior in classes of different ability levels."[2] The authors describe an observational instrument which was devised to identify those behaviors that actually occur in the classroom.

Evans and Balser describe another instrument which was developed for describing the behavior of secondary school biology teachers.[3] Using videotape records of classroom activities, the researchers developed a detailed procedure for evaluating the teacher activities and behaviors. Their study deals with all of the behaviors of the teacher, however, and not only those which pertain directly to the intellectual goals of the course.

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[1]Abraham S. Fischler and George Zimmer, "The Development of An Observational Instrument for Science Teaching," Journal of Research in Science Teaching, V (1967-1968), 127-137.

[2]Ibid., p. 127.

[3]Thomas P. Evans and LeVon Balser, "An Inductive Approach to the Study of Biology Teacher Behaviors," Journal of Research in Science Teaching, VII (1970), 47-56.

The foregoing discussion reveals that extensive effort has been devoted to teaching science in general and beginning college physics in particular. The physics profession has committed extensive resources to its improvement, clear goals have been stated, and extensive supporting instructional material has been developed. Similarly, the research in higher education has been addressed to a number of problems dealing with instruction. Largely missing from the literature, however, is any detailed study of the teaching practices in introductory college physics. The majority of available research on science teaching practices, as is cited above, is concerned with the elementary and secondary school levels.

Similar concern is expressed by Fraser in a review of the research devoted to college science teaching. He states:

> There seems to be a definite need for motivating a larger number of college teachers to do research in the teaching of science. The limited number of investigations reported for the college level is disturbing, expecially in view of the fact that: all college teachers of science are in a sense science educators, and presumably are vitally concerned with the improvement of instruction.[1]

Fraser raises the further question: "What has been learned about research in the teaching of science at the college level? How can this contribute more realistically to the improvement of science instruction at this level?"[2]

Missing also from the recommendations of the various conferences on the teaching of beginning college physics is any specific suggestion of the instructional procedures required to implement the stated goals.

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[1]Thomas P. Fraser, et. al., "Review of Recent Research in the Teaching of Science at the College Level III," Science Education, XXXIX (December, 1955), 370.

[2]Ibid.

A number of questions remains unanswered as to the impact of these recommendations on the individual instructor and on the activities which he employs in implementing the goals of the introductory physics course.

CHAPTER III

PROCEDURES AND SAMPLE

The data for this study were gathered by personally interviewing the professors chosen in the sample and by visiting his classes. Each class visit was audio-tape recorded for further analysis. During the interview, each instructor was requested to provide information concerning his objectives for the course and for the class he had just completed.

The instruments designed to determine the instructor's course objectives and for the class visited were based, in part, upon the recommendations of the AIP committee on the role of physics in engineering education and on the reports of the Carleton and Denver Conferences which were discussed in Chapter I. Four preliminary instruments were developed, and these were tested in several classes in colleges which did not participate in the study. (These instruments are provided in Appendix A, Exhibits 1,2,3, and 4.) At the same time, these instruments were sent to twelve college physics professors all in different universities across the country, who had shown interest in introductory physics through their publications. Copies of the instrument were also sent to the director of the Commission on College Physics, who circulated them to the various commissioners and requested their opinions also. In all, response was received from seven of the original twelve professors and from three commissioners. The response of each toward the research was favorable, and the four instruments were revised to reflect the comments which were received.

Immediately after each class visit the instructor was asked to complete a form in which he listed specific information about the course (Appendix A, Exhibit 1). He also was asked to provide information regarding the purposes of the class he had just completed (Appendix A, Exhibit 1). The first time each instructor was visited he was also asked to provide information on the purposes he believed to be important for the course he was teaching (Appendix A, Exhibit 2).

In addition to the taped record of the class, notes were made on any demonstrations which were conducted during the class (Appendix A, Exhibit 3). These notes provided a record of the way in which the teacher conducted the demonstration in terms of teacher-student activities. Other instructor activities such as teaching methods, use of visual aids, class assignments, and references to laboratory work were also recorded (Appendix A, Exhibit 4).

The tape recordings of the classroom visits were between 40 and 45 minutes of actual class time; this time was somewhat variable because class was occasionally dismissed before the allotted time was up. The first five minutes after class began was not recorded to allow for such mechanical details as initial announcements and review. No previous announcement of class visits was made to the instructor before the first visit. The instructor was informed that there would be a second visit, but he was not informed as to the time of this visit. Permission from the department head of each department visited was obtained in advance.

The tape recording of the lesson was then analyzed to determine the teacher behavior during the class in terms of the questions which he asked and the amount of time he devoted to particular teaching methods. The form used for this purpose is given in Appendix A, Exhibit 5. The questions asked by the instructor, as recorded on the tape of the class, were classified into two overlapping groups. The first group concerns the type of question and the manner in which it was asked. This category pertained to the teacher's behavior and to the way he asked a given question. Types of questions included directive, leading, divergent, convergent, and rhetorical. Definitions of each of these types of questions follow:

1. Directive: A directive question is one that calls the student's attention to a particular thought or action. Examples are: "What is the reading of the meter?" "What did you observe?"

2. Leading: Questions that serve to guide the student in clarifying his ideas are leading questions. Leading questions may help a student come to a better formulation of an idea or may serve to point out in-assuracies in it. For example, "How could you state that in another way?" "How does this compare with what you said before?"

3. Divergent: A divergent question is one which suggests a wider range of consideration of an idea by a student. For example, "How do the data support your conclusion?"

4. Convergent: A convergent question is one intended to narrow the area of thought of a student. It is directed toward a specific idea or group of ideas. "What is that finding related to?" "What principle does that illustrate?"

5. Rhetorical: A rhetorical question is a question posed with no

answer expected. It may be immediately answered by the teacher or is one in which a group response is expected. "The acceleration of a freely falling object is. . . ?" "Are all of the conditions of the problem now satisfied?--Yes!"

The second way in which a teacher's questions were classified was in terms of the purpose of the question or the action or response expected from the student. These responses include knowledge, comprehension, application, analysis, synthesis, evaluation, opinion, and observation. Each of these responses, with the exception of opinion and observation is discussed in detail by Bloom.[1] Definitions of each of these terms are as follows:

1. Knowledge:

> Knowledge as defined here includes those behaviors and test situations which emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena.[2]

Basically, knowledge as used in this research will be taken to mean recall.

2. Comprehension:

> Here we are using the term "comprehension" to include those objectives, behaviors, or responses which represent an understanding of the literal message contained in a communication.[3]

Bloom includes under the term "comprehension" such behaviors as interpretation, translation, and extrapolation.

3. Application: Application can be best defined by contrasting it with comprehension.

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[1]Bloom, *Taxonomy*. It should be noted that Bloom subdivides these categories into much finer classification groups. It did not seem to be particularly advantageous to carry out this detailed breakdown for this research. For example, Bloom employs nine subdivisions for the classification of "Knowledge." At the same time, the other responses have at most three subdivisions. This detailed analysis seemed beyond the more general goals of this research.

[2]*Ibid.*, p. 62.

[3]*Ibid.*, p. 89.

A demonstration of "Comprehension" shows that the student can use the abstraction when its use is specified. A demonstration of "Application" shows that he will use it correctly, given an appropriate situation in which no mode of solution is specified.[1]

4. Analysis:

Analysis emphasizes the breakdown of the material into its constituent parts and detection of the relationships of the parts and of the way they are organized.[2]

5. Synthesis:

Synthesis is here defined as the putting together of elements and parts so as to form a whole. This is a process of working with elements, parts, etc., and combining them in such a way as to constitute a pattern or structure not clearly there before.[3]

6. Evaluation:

Evaluation is defined as the making of judgements about the value, for some purpose, of ideas, works, solutions, methods, material, etc. It involves the use of criteria as well as standards for appraising the extent to which particulars are accurate, effective, economical, or satisfying. The judgements may be either quantitative or qualitative, and the criteria may be either those determined by the student or those which are given to him.[4]

7. Opinion: While opinion is not classified by Bloom, there were questions which some instructors posed that required an expression of opinion on the part of the student. These were questions on which there was inadequate data or information to make a proper evaluation. An opinion question, in any case, required the student to take a stand on an issue for the purpose of further clarification or illustration.

8. Observation: In the sciences the role of observation is important. Questions requiring student observation were included in this category.

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[1]*Ibid.*, p. 120.

[2]*Ibid.*, p. 144.

[3]*Ibid.*, p. 162.

[4]*Ibid.*, p. 185.

This category also was not classified by Bloom.

Any question asked, therefore, was cross-classified by both type and purpose. For example, the question "What is the direction of that force?" is classified as a directive question and also as a comprehension question.

Sample

The sample of classes which was studied was drawn from the two state universities and four of the six state colleges in Oklahoma. The universities each offer studies in physics through the doctoral level. Each of the state colleges offers an undergraduate physics major and some work that applies toward a minor for the masters degree in Education. Examination of faculty bulletins for each of these institutions reveals that the faculty is drawn from a wide number of universities, so that the possible influence of any one university is not predominate on the teaching practices of the sample institutions.

Classes in beginning physics visited were selected from the published class schedule for each college for the Spring, 1971 semester. Classes to be visited were selected in two ways. At the state colleges classes were selected so that most of the instructors were visited. Because of the large number of sections for each course at the two state universities, sections were selected every other hour on the days the institution was visited. About half of the sections of each course were selected. This selection provided about equal numbers of classes covering material taught in both the first and the second semester of a two-semester sequence. In all, twenty-four instructors were finally included in the survey. Each section and each instructor was visited twice with the exception of three instructors at two colleges who were visited only once. One of these instructors was giving an examination on the day of the second visit; the semester terminated before a second visit could be made to two instructors at one state college. Visits were conducted between mid-February and mid-May, 1971. A sufficient number of classes was selected to provide a representative sample of the teaching practices employed by each instructor for the particular class visited.

CHAPTER IV

PRESENTATION OF DATA

Nine questions regarding the teaching of introductory physics were raised in the statement of the research problem presented in Chapter I. The data gathered to answer those questions will be presented in this chapter. Evaluation and discussion of the data will be reserved for Chapter V.

The first question asked was: "What goals do college teachers espouse as being most important in the beginning course?" At the time of the investigator's first visit each instructor was asked to complete Exhibit 2 (Appendix A). This form lists fourteen objectives for the teaching of introductory physics. These objectives are:

1. An understanding of physics as a process of inquiry.
2. An understanding of the basic concepts and principles of physics.
3. Engender in the student a curiosity about the natural world.
4. An understanding of the importance of mathematical formulation of physical principles.
5. An understanding of the historical development of physical concepts.
6. An appreciation and understanding of the role of experimentation in physics.
7. The importance of approaching problems outside of science with critical judgement.
8. A tool for studies outside of physics, e.g. medicine.

9. The relationship (and differences) between science and technology.

10. An understanding of the limitations and changes of scientific theories.

11. The relationship between physics and other areas of science.

12. The relationship between physics and other areas of study, e.g., history, sociology, English, etc.

13. An ability to understand and appreciate the goals and methods of current scientific research.

14. Other (please specify).

The data obtained are summarized in Tables 1 through 10. These tables list the frequency that each objective is ranked among the five most important objectives of the course. These tables also indicate the frequency that the instructors considered a given course objective as "most important" in the course (M), as having "some importance" (S), or as having "little or no importance" (N).

Tables 1, 2, and 3 reflect the frequency of course objectives stated by instructors having less than five years teaching experience, between five and fifteen years teaching experience, and more than fifteen years teaching experience.

Tables 4 and 5 summarize the frequency of course objectives by instructors at the four state colleges and at the two state universities.

Tables 6, 7, 8, and 9 summarize the frequency of course objectives of instructors of courses for "All Types of Students," for "Liberal Arts Majors and Pre-Professional Students," for "Physical Science and Engineering Students," and for "Elementary Teachers."

Table 10 summarizes the total frequency of course objectives expressed by all twenty-four instructors who were interviewed.

Two instructors indicated "Other" objectives. The objectives they stated were:

1. "To look for alternatives and make decisions based on evidence of an experiment."

2. "To insulate them (the students) somewhat from feelings of hostility engendered in the uninformed population by scientific innovations which tend to make major changes in their lives; i.e. 'future shock.'"

TABLE 1

FREQUENCY OF COURSE OBJECTIVES OF TEN INSTRUCTORS
HAVING LESS THAN FIVE YEARS TEACHING EXPERIENCE

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	2	1	2	1	1	7	8	2	0
2	7	1	0	1	0	9	9	1	0
3	0	1	2	0	2	5	6	3	1
4	1	3	1	0	0	5	5	5	0
5	0	1	0	0	1	2	1	7	2
6	0	0	0	2	2	4	2	8	0
7	0	0	2	0	1	3	1	6	3
8	0	3	0	1	0	4	3	4	3
9	0	0	0	3	0	3	4	4	2
10	0	0	3	1	0	4	5	2	3
11	0	0	0	0	1	1	1	8	1
12	0	0	0	0	1	1	0	3	8
13	0	0	0	1	1	2	0	8	2
14	0	0	0	0	0	0	0	0	0

TABLE 2

FREQUENCY OF COURSE OBJECTIVES OF SEVEN INSTRUCTORS
HAVING BETWEEN FIVE AND FIFTEEN
YEARS TEACHING EXPERIENCE

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	3	2	1	1	1	8	6	1	0
2	2	2	1	0	0	5	6	1	0
3	0	1	2	0	1	4	5	2	0
4	0	0	0	2	1	3	3	4	0
5	0	0	0	0	0	0	1	6	0
6	0	1	0	1	1	3	4	3	0
7	1	0	2	0	0	3	3	4	0
8	0	0	0	2	1	3	3	2	2
9	0	0	0	0	0	0	0	3	4
10	0	0	1	0	1	2	3	3	1
11	0	2	0	0	1	3	3	3	1
12	0	0	0	0	0	0	0	3	4
13	0	0	0	0	0	0	1	2	3
14	0	0	0	1	0	1	1	0	0

TABLE 3

FREQUENCY OF COURSE OBJECTIVES OF SEVEN INSTRUCTORS
HAVING MORE THAN FIFTEEN YEARS
TEACHING EXPERIENCE

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	2	2	0	0	0	4	4	3	0
2	4	2	1	2	0	9	7	0	0
3	0	0	0	0	3	3	6	1	0
4	0	0	1	0	1	2	1	5	1
5	0	0	0	0	0	0	0	6	1
6	0	3	1	0	0	4	4	3	0
7	0	0	0	1	1	2	2	4	1
8	1	0	0	2	0	3	2	5	0
9	0	0	0	0	0	0	1	1	5
10	0	0	3	1	0	4	4	2	1
11	0	0	1	0	1	2	2	4	1
12	0	0	0	0	0	0	0	4	3
13	0	0	0	1	1	2	4	2	1
14	0	0	0	0	0	0	0	0	0

TABLE 4

FREQUENCY OF COURSE OBJECTIVES OF NINE INSTRUCTORS
AT THE STATE COLLEGES

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	0	4	1	2	1	8	7	2	0
2	7	1	1	0	0	9	9	0	0
3	0	0	1	1	4	6	6	3	0
4	0	1	1	1	1	4	4	5	0
5	0	0	0	0	2	2	0	9	0
6	0	1	1	0	0	2	3	6	0
7	1	0	2	1	0	4	4	3	2
8	1	0	0	4	1	6	4	4	1
9	0	0	0	0	0	0	1	4	4
10	0	0	1	0	0	1	2	5	2
11	0	2	1	0	0	3	2	6	1
12	0	0	0	0	0	0	0	3	6
13	0	0	0	0	0	0	2	4	3
14	0	0	0	0	0	0	0	0	0

TABLE 5

FREQUENCY OF COURSE OBJECTIVES OF FIFTEEN INSTRUCTORS AT THE STATE UNIVERSITIES

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	7	0	2	0	1	10	11	4	0
2	7	4	1	1	0	13	13	2	0
3	0	2	3	1	2	8	11	3	1
4	1	2	1	1	0	5	5	9	1
5	0	1	0	0	0	1	2	10	3
6	0	3	0	3	3	9	7	8	0
7	0	0	2	1	2	4	2	11	2
8	0	3	0	1	0	4	4	7	4
9	0	0	0	3	0	3	4	4	7
10	0	0	6	2	1	9	10	2	3
11	0	0	0	0	3	3	4	9	2
12	0	0	0	0	1	1	0	7	8
13	0	0	0	2	2	4	3	9	3
14	0	0	0	1	0	1	1	0	0

TABLE 6

FREQUENCY OF COURSE OBJECTIVES OF INSTRUCTORS OF COURSES FOR ALL TYPES OF STUDENTS[a]

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	0	1	0	0	1	2	1	1	0
2	2	0	0	0	0	2	2	0	0
3	0	0	0	1	0	1	1	1	0
4	0	0	0	0	1	1	0	2	0
5	0	0	0	0	0	0	0	2	0
6	0	0	1	0	0	1	1	1	0
7	0	0	1	0	0	1	1	0	1
8	0	0	0	1	0	1	1	1	0
9	0	0	0	0	0	0	0	0	2
10	0	0	0	0	0	0	0	2	0
11	0	1	0	0	0	1	1	1	0
12	0	0	0	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	2
14	0	0	0	0	0	0	0	0	0

[a]Two Instructors

TABLE 7

FREQUENCY OF COURSE OBJECTIVES OF INSTRUCTORS
OF COURSES FOR LIBERAL ARTS MAJORS
AND PRE-PROFESSIONAL STUDENTS[a]

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	3	2	2	1	0	8	8	3	0
2	5	2	2	1	0	10	10	1	0
3	0	1	1	0	4	6	7	4	0
4	1	0	1	1	1	4	4	6	1
5	0	1	0	0	0	1	1	9	1
6	0	3	0	1	0	4	4	7	0
7	1	0	1	1	1	4	2	9	0
8	1	1	0	3	1	6	5	5	1
9	0	0	0	1	0	1	1	5	5
10	0	0	4	1	0	5	4	4	3
11	0	1	0	0	1	2	3	7	1
12	0	0	0	0	1	1	0	6	5
13	0	0	0	1	2	3	4	5	2
14	0	0	0	0	0	0	0	0	0

[a]Eleven Instructors

TABLE 8

FREQUENCY OF COURSE OBJECTIVES OF INSTRUCTORS OF COURSES FOR PHYSICAL SCIENCE AND ENGINEERING STUDENTS[a]

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	2	1	1	1	1	6	7	2	0
2	7	2	0	0	0	9	9	0	0
3	0	0	2	1	2	5	7	1	1
4	0	3	1	1	0	5	5	4	0
5	0	0	0	0	1	1	0	7	2
6	0	1	0	1	3	5	4	5	0
7	0	0	1	0	1	2	2	4	3
8	0	2	0	1	0	3	2	5	2
9	0	0	0	2	0	2	4	2	3
10	0	0	3	1	0	4	7	1	1
11	0	0	1	0	1	2	1	6	2
12	0	0	0	0	0	0	0	3	6
13	0	0	0	1	0	1	1	8	0
14	0	0	0	0	0	0	0	0	0

[a]Nine Instructors

TABLE 9

FREQUENCY OF COURSE OBJECTIVES OF INSTRUCTORS OF COURSES FOR ELEMENTARY TEACHERS[a]

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	2	0	0	0	0	2	2	0	0
2	0	1	0	0	0	1	1	1	0
3	0	1	1	0	0	2	2	0	0
4	0	0	0	0	0	0	0	2	0
5	0	0	0	0	0	0	1	1	0
6	0	0	0	1	0	1	1	1	0
7	0	0	1	0	0	1	1	1	0
8	0	0	0	0	0	0	0	0	2
9	0	0	0	0	0	0	0	1	1
10	0	0	0	0	1	1	1	0	1
11	0	0	0	0	1	1	1	1	0
12	0	0	0	0	0	0	0	1	1
13	0	0	0	0	0	0	0	0	2
14	0	0	0	1	0	1	0	0	0

[a]Two Instructors

TABLE 10

FREQUENCY OF COURSE OBJECTIVES BY
TWENTY-FOUR INSTRUCTORS

Objective No.	Rank of Objective								
	1	2	3	4	5	Total	M	S	N
1	7	4	3	2	2	18	18	6	0
2	14	5	2	1	0	22	22	2	0
3	0	2	4	2	6	14	17	6	1
4	1	3	2	2	2	10	9	14	1
5	0	1	0	0	1	2	2	19	3
6	0	4	1	3	3	11	10	14	0
7	1	0	4	1	2	8	5	15	4
8	1	3	0	5	1	10	9	11	4
9	0	0	0	3	0	3	5	8	11
10	0	0	7	2	1	10	11	8	5
11	0	2	1	0	3	6	7	14	3
12	0	0	0	0	1	1	0	10	14
13	0	0	0	2	2	4	5	13	6
14	0	0	0	1	0	1	1	1	0

The second question in this research was directed toward the objectives of the particular class period observed. At the time of each visit the instructor was asked to complete the check list provided in Exhibit 1 (Appendix A). The data summarized from these check lists is provided in Table 11. More than one objective was checked as having primary importance or secondary importance by several instructors. These objectives were interpreted as being equally important in compiling the table. Similarly some instructors expressed no preference for certain objectives. These are so indicated in the table.

Seven instructors indicated "Other" objectives for the class period. These objectives were:

1. "To articulate outside reading on a specific topic."

2. "To understand physics as a part of our culture."

3. "To appreciate the paradoxical nature of interpretations of modern physics and human-ness (sic) of scientists."

4. "Application of previous work to specific problems (Quiz review)."

5. Since eight out of twelve students in the class are foreign students, the period was conducted in such a way as to give the student a chance to express himself orally as well as to clarify any questions about the problem assignment. (Paraphrased from the instructor's statement.)

6. "For the most part I spelled out the steps involved in the scientific method and tried to get students to recall how the scientific method was used historically. I emphasized the importance of observation and inductive reasoning in the scientific method."

7. "To solve assigned problems."

The researcher also sought to determine the methods of instruction employed by the instructors as well as the type of questions and the purpose of the questions which they asked. Analysis of the audio-tape records

TABLE 11

FREQUENCY OF OBJECTIVES OF INDIVIDUAL CLASS PERIODS[a]

Objective No.	Rank of Frequency							
	1	2	3	4	5	6	NA	no preference stated
1	26	10	2	3	0	0	0	4
2	4	6	4	6	2	0	7	16
3	8	5	9	2	3	0	6	12
4	6	14	5	2	5	0	2	11
5	6	10	9	6	2	2	0	10
6	5	4	1	3	2	6	10	14
Other	5	0	0	1	0	0	0	39

[a]Forty-five class periods

of each class visit revealed information on these items. The categories of questions were defined in Chapter III. The information gathered from the audio-tapes on the methods of instruction (or "Lecture Emphasis") is presented in terms of the time devoted to each of four categories. These categories are: description or qualitative explanation of concepts or principles; working problems or examples; derivation of formulas; and demonstrations. The percentage of total time which was devoted to each category is also given.

The data on the instructor questions and instruction emphasis are presented together in Tables 12 through 21. The figures in the body of the table are the number of questions asked in each category; the figures in parentheses are the percentages of the total number of questions that were asked in that category. (Differences in marginal totals of percentages are due to rounding errors.)

Tables 12, 13, and 14 present respectively the data for those instructors having less than five years teaching experience, between five and fifteen years teaching experience, and more than fifteen years teaching experience.

Tables 15 and 16 summarize the data for those instructors at the four state colleges and at the two state universities.

Tables 17, 18, 19, and 20 present the data for instructors of courses for "All Types of Students," for "Liberal Arts Majors and Pre-Professional Students," for "Physical Science and Engineering Students," and for "Elementary Teachers."

Table 21 summarizes the data for all twenty-four instructors who were visited.

TABLE 12

QUESTIONS ASKED BY INSTRUCTORS HAVING LESS THAN FIVE YEARS TEACHING EXPERIENCE

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge				3 (2.9)[a]	9 (8.7)	12 (11.6)
Comprehension		2 (1.9)		24 (23.3)	30 (29.1)	56 (54.4)
Application			1 (1.0)	8 (7.8)	21 (20.4)	30 (29.1)
Analysis				2 (1.9)	3 (2.9)	5 (4.8)
Synthesis						
Evaluation						
Opinion						
Total		2 (1.9)	1 (1.0)	37 (35.9)	63 (61.2)	103 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	470.0	58.0
Working problems or examples	281.0	34.6
Derivation of formulas	60.0	7.4
Demonstrations	0	0
Total	811.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 13

QUESTIONS ASKED BY INSTRUCTORS HAVING BETWEEN FIVE AND FIFTEEN YEARS TEACHING EXPERIENCE

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge				24 (10.7)[a]	33 (14.7)	57 (25.4)
Comprehension		5 (2.2)	3 (1.3)	49 (21.9)	87 (38.8)	144 (64.3)
Application				12 (5.4)	3 (1.3)	15 (6.7)
Analysis						
Synthesis						
Evaluation						
Opinion		2 (0.9)		5 (2.2)	1 (0.4)	8 (3.6)
Total		7 (3.1)	3 (1.3)	90 (40.2)	124 (55.4)	224 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	312.5	63.3
Working problems or examples	171.0	34.6
Derivation of formulas	7.5	1.5
Demonstrations	2.5	0.6
Total	493.5	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 14

QUESTIONS ASKED BY INSTRUCTORS HAVING MORE THAN FIFTEEN YEARS TEACHING EXPERIENCE

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		6 (1.6)[a]	3 (0.8)	44 (11.7)	41 (10.9)	94 (25.1)
Comprehension		15 (4.0)	7 (1.9)	101 (26.9)	119 (31.7)	242 (64.5)
Application			6 (1.6)	21 (5.6)	11 (2.9)	38 (10.1)
Analysis						
Synthesis						
Evaluation						
Opinion				1 (0.27)		1 (0.27)
Total		21 (5.6)	16 (4.3)	167 (44.5)	171 (45.6)	375 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	210.5	37.4
Working problems or examples	297.0	52.8
Derivation of formulas	37.0	6.6
Demonstrations	18.0	3.2
Total	562.5	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 15

QUESTIONS ASKED BY INSTRUCTORS AT THE STATE COLLEGES

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		1 (0.3)[a]	3 (0.9)	31 (9.5)	26 (8.0)	61 (18.7)
Comprehension		16 (4.9)	7 (2.2)	76 (23.3)	125 (38.3)	224 (68.7)
Application			7 (2.2)	23 (7.1)	10 (3.1)	40 (12.3)
Analysis						
Synthesis						
Evaluation						
Opinion					1 (0.3)	1 (0.3)
Total		17 (5.2)	17 (5.2)	130 (39.9)	162 (49.7)	326 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	367.0	58.7
Working problems or examples	212.0	33.9
Derivation of formulas	33.5	5.4
Demonstrations	12.5	2.0
Total	625.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 16

QUESTIONS ASKED BY INSTRUCTORS AT THE STATE UNIVERSITIES

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		5 (1.3)[a]		40 (10.6)	57 (15.2)	102 (27.1)
Comprehension		6 (1.6)	3 (0.8)	98 (26.1)	112 (29.8)	219 (58.2)
Application				18 (4.8)	24 (6.4)	42 (11.2)
Analysis				2 (0.5)	3 (0.8)	5 (1.3)
Synthesis						
Evaluation						
Opinion		2 (0.5)		6 (1.6)		8 (2.1)
Total		13 (3.5)	3 (0.8)	164 (43.6)	196 (52.1)	376 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	626.0	50.4
Working problems or examples	537.0	43.2
Derivation of formulas	71.0	5.7
Demonstrations	8.0	0.6
Total	1242.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 17

QUESTIONS ASKED BY INSTRUCTORS OF COURSES FOR ALL TYPES OF STUDENTS

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		1 (0.6)[a]	1 (0.6)	10 (6.0)	13 (7.8)	25 (15.0)
Comprehension		9 (5.4)	1 (0.6)	34 (20.4)	76 (45.5)	120 (71.8)
Application			3 (1.8)	10 (6.0)	9 (5.4)	22 (13.2)
Analysis						
Synthesis						
Evaluation						
Opinion						
Total		10 (6.0)	5 (3.0)	54 (32.3)	98 (58.7)	167 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	72.0	48.2
Working problems or examples	58.0	38.8
Derivation of formulas	19.5	13.0
Demonstrations	0	0
Total	149.5	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 18

QUESTIONS ASKED BY INSTRUCTORS OF COURSES FOR LIBERAL ARTS MAJORS AND PRE-PROFESSIONAL STUDENTS

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		5 (1.6)[a]	1 (0.3)	32 (10.3)	45 (14.5)	83 (26.7)
Comprehension		6 (1.9)	5 (1.6)	66 (21.2)	122 (39.2)	199 (63.9)
Application			2 (0.6)	17 (5.5)	9 (2.9)	28 (9.0)
Analysis						
Synthesis						
Evaluation						
Opinion					1 (0.3)	1 (0.3)
Total		11 (3.5)	8 (2.6)	115 (37.0)	177 (56.9)	311 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	502.5	58.4
Working problems or examples	317.0	36.9
Derivation of formulas	28.5	3.3
Demonstrations	12.0	1.4
Total	860.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 19

QUESTIONS ASKED BY INSTRUCTORS OF COURSES FOR PHYSICAL SCIENCE AND ENGINEERING STUDENTS

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge			1 (0.7)[a]	7 (4.9)	12 (8.4)	20 (14.1)
Comprehension		4 (2.8)	1 (0.7)	46 (32.4)	32 (22.5)	83 (58.4)
Application			2 (1.4)	14 (9.8)	17 (12.0)	33 (23.2)
Analysis				2 (1.4)	3 (2.1)	5 (3.5)
Synthesis						
Evaluation						
Opinion				1 (0.7)		1 (0.7)
Total		4 (2.8)	4 (2.8)	70 (49.3)	64 (45.1)	142 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	307.5	42.2
Working problems or examples	359.5	49.3
Derivation of formulas	56.5	7.7
Demonstrations	6.0	0.8
Total	729.5	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 20

QUESTIONS ASKED BY INSTRUCTORS OF COURSES
FOR ELEMENTARY TEACHERS

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge				22 (26.8)[a]	13 (15.8)	35 (42.7)
Comprehension		3 (3.7)	3 (3.7)	28 (34.2)	6 (7.3)	40 (48.8)
Application						
Analysis						
Synthesis						
Evaluation						
Opinion		2 (2.4)		5 (6.1)		7 (8.5)
Total		5 (6.1)	3 (3.7)	55 (67.1)	19 (23.2)	82 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	111.0	86.7
Working problems or examples	14.5	11.3
Derivation of formulas	0	0
Demonstrations	2.5	2.0
Total	128.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

TABLE 21

QUESTIONS ASKED BY ALL TWENTY-FOUR INSTRUCTORS

Purpose of Question	Type of Question					
	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge		6 (0.8)[a]	3 (0.4)	71 (10.2)	83 (11.8)	163 (23.3)
Comprehension		22 (3.1)	10 (1.4)	174 (24.8)	236 (33.6)	442 (62.9)
Application			7 (1.0)	41 (5.8)	35 (5.0)	83 (11.8)
Analysis				2 (0.3)	3 (0.4)	5 (0.7)
Synthesis						
Evaluation						
Opinion		2 (0.4)		6 (0.8)	1 (0.1)	9 (1.4)
Total		30 (4.4)	20 (2.8)	294 (41.9)	358 (51.0)	702 (100)

LECTURE EMPHASIS	Time (min.)	% Total Time
Description or qualitative explanation of concepts or principles	933.0	53.2
Working problems or examples	749.0	40.1
Derivation of formulas	104.5	5.6
Demonstrations	20.5	1.1
Total	1867.0	100

[a]Figures in parentheses are the percentages of the total number of questions for each category.

Notes were made on selected instructor activities at the time of each class visit (Appendix A, Exhibit 4). These notes are summarized in Table 22.

In the twenty-four different sections of introductory physics that were visited, eleven different textbooks were assigned. A list of these books is provided in Table 23.

This chapter has served to summarize the essential data that were gathered in the course of this research. The discussion and conclusions drawn from these data will be given in Chapter V.

TABLE 22

FREQUENCY OF INSTRUCTOR ACTIVITIES
IN 45 OBSERVED CLASSES

Activity	Frequency	
The instructor:	Yes	No
1. Followed text closely	30	15
2. Diverged substantially from text	15	30
3. Used appropriate visual aids:		
a. Blackboard	43	2
b. Overhead projector	6	39
c. 16 mm. projector	1	44
4. Employed appropriate demonstrations	3	42
5. Recommended outside reading	1	44
6. Required outside reading	1	44
7. Problem assignment[a]	22	23
8. Referred to previous laboratory work	2	43
9. Referred to future laboratory work	2	43

[a]"Yes" was checked if problems were assigned for completion at a future date or if a previous assignment was discussed.

TABLE 23

TEXTBOOKS USED BY CLASSES VISITED IN STUDY

1. Ashford, Theodore. The Physical Sciences From Atoms to Stars. 2nd ed. New York: Holt, Rinehart, and Winston, 1967.
2. Ballif, Jae R. and Dibble, William E. Conceptual Physics: Matter in Motion. New York: John Wiley & Sons, 1969.
3. Borowitz, Sidney and Bornstein, Lawrence A. Contemporary View of Elementary Physics. McGraw-Hill Book Company, Inc. 1968.
4. Ford, Kenneth. Basic Physics. Waltham, Mass.: Blaisdell Publishing Company, 1968.
5. Halliday, David and Resnick, Robert. Physics for Students of Science and Engineering. Part II. New York: John Wiley & Sons, Inc., 1962.
6. Halliday, David and Resnick, Robert. Fundamentals of Physics. New York: John Wiley & Sons, Inc., 1970.
7. March, Robert H. Physics for Poets. New York: McGraw-Hill Book Company, Inc., 1970.
8. Miller, Franklin J., Jr. College Physics. 2nd ed. New York: Harcourt, brace & Jovanovich, Inc., 1967.
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10. Semat, Henry. Fundamentals of Physics. 4th ed. New York: Holt, Rinehart, & Winston, Inc., 1966.
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CHAPTER V

ANALYSIS OF DATA AND CONCLUSIONS

Introductory physics is an important course in the college curriculum. It serves as an introduction to physics for those who will pursue it as a college major; it is an essential course for engineering students; and it is a requirement for pre-medical and pre-dental students. For those who elect, physics may fulfill the liberal arts science requirement. The introductory physics course, then serves as an introduction to those who will study physics and/or science in depth and as a terminal course for many who will not pursue physics or science any further. The courses which were observed in this research reached each of these groups of students.

Analysis

The preference of course objectives summarized in Tables 1 through 10 reveals a priority of objectives which are held by those engaged in teaching introductory physics. Examination of each table reveals that objectives 1 and 2 were most frequently selected as the most important objectives of the course. As Table 10 shows, objective 2 was most often selected as the most important objective and was most often selected among the five most important objectives. The data do not support any distinction among instructors based on their years of experience, the type of institution, or the type of course which they taught. Objective 2 is primarily concerned with the subject content of the course. Objective 1 implies concern for the methodology and nature of physics as "a process of inquiry."

Objectives 4 and 6, dealing with the mathematical formulation of physical principles and the role of experimentation, are given intermediate importance. These objectives deal with important aspects of physical inquiry. Experimentation, being an important part of scientific inquiry, received a lower ranking than was expected due to the high ranking received by objective 1.

Objective 3, "to engender in the student a curiosity about the natural world," received a high ranking as being most important in the course, and ranked third highest among the five most important objectives of all of the instructors.

Those objectives dealing with the effects of various cultural forces on the development of physics (objectives 5, 9, and 10) and the effects of physics upon our culture (objectives 7, 11 and 12) received the lowest priorities. Indeed, more instructors indicated objectives 9 and 12 as having "little or no importance" to the course than any of the other objectives. Objective 10 received slightly higher ranking from those instructors of courses for physical science and engineering students than from instructors of the other courses. Otherwise, no marked differences were noted among the other groups in their degree of preference of these objectives.

The stated objectives of the individual class periods, summarized in Table 11, are consistent with the overall course objectives. Objective 1 "to familiarize the student with the physical principles of the topic(s) of the lesson," was given primary importance for 26 of the 45 classes visited and secondary importance for 10 other classes. Thus, the subject matter of physics is given highest priority for both the course itself and the individual class periods. Objectives 4 and 5, dealing with an appreciation for the usefulness of physics in understanding the natural world and the use of mathematical formulation of physical problems, received the next highest frequencies for the second most important objective. Objective 6, the historical development of physical theories, received the lowest overall ranking. This course objective also received a low ranking.

The types of questions asked by the instructors and the purposes of these questions provided valuable information on the intellectual goals which these instructors actually pursued in the classroom. Tables 12 through 21 summarize the classification of the questions which were asked during the class visits, along with the respective percentage of the total number of each type of question that was asked.

Examination of Tables 12, 13, and 14 reveals several differences and similarities among instructors with different amounts of teaching experience. Ten instructors were observed who had less than five years teaching experience; seven instructors were observed who had between five and fifteen years experience; and seven instructors were observed who had more than fifteen years experience. The total number of questions asked by each of these three groups of instructors increased with the number of years teaching experience. Although there were three more instructors visited who had less than five years experience than in either of the other categories, this group asked only 103 questions compared to 224 and 375 questions, respectively, for the next two groups of seven instructors each.

Examination of the types of questions asked also reveals that a higher percentage of rhetorical questions was asked by the group having fewer years of experience. The percentages range from 61.2% for instructors with less than five years experience to 45.6% for instructors having more than fifteen years experience. A somewhat larger percentage of questions dealing with application (29.1%) were asked by instructors with less than five years teaching experience as compared to the other two groups.

A comparison of the questions asked by instructors at the state colleges and the state universities (Tables 15 and 16) reveals no significant differences between the two types of institutions. Similarly, no major differences are noted among those instructors of courses for different groups of students (Tables 17, 18, 19, and 20). One exception is noted in Table 19, where a higher percentage (23.2%) of application questions was asked by instructors of courses for physical science and engineering students.

The summary of questions asked by all twenty-four instructors (Table 21) provides a representative summary of the data presented in the previous nine tables. These questions were cross classified in two ways--by question type and by question purpose. Of those questions classified as to type, convergent and rhetorical questions comprised 92.9% of the total (the sum of the two bottom marginal percentages). The convergent questions were directed toward one response only and did not provide opportunity for a detailed examination of the idea which was being discussed. Similarly, while the rhetorical questions may have required some passive response on the part of the student, this response was never expressed since the instructor provided the answer.

Of those questions related to question purpose, questions involving knowledge and comprehension comprised 86.2% of the total (the sum of the two right side marginal percentages). Questions requiring a knowledge response demand only recall on the part of the student. Those questions involving comprehension require only the most basic understanding and extension of the ideas involved in the question. Indeed, the four cells in Table 21 representing convergent and rhetorical questions and knowledge and comprehension questions include 80.4% of all of the questions which were asked.

Thus the vast majority of the questions which were asked by the instructors visited during this research demanded, at best, superficial response from the students. Those questions which would require greater depth of thought--analysis, synthesis, and evaluation--received minimal attention. Indeed, of the three, analysis was the only question observed at all. Of the ways the questions were asked, those types of questions requiring the greatest student thought--leading and divergent--also received minimal attention. One concludes, therefore, that based on the questions asked, the content of physics is given highest priority and student involvement the lowest priority by the instructors. In spite of the fact that the instructors ranked the objective, "understanding physics as a process of inquiry," a high second place among the objectives for their course, the nature of the questions they asked place this objective far lower in terms of their actual teaching practices.

A comparison of the "Lecture Emphasis" percentages of Tables 12 through 21 reveals that a major portion of time is devoted to explanation of concepts or principles. Working problems or examples occupies a close second place in importance. The small percentage of time devoted to demonstrations reveals that demonstrations seem to hold a low priority among teaching methods in spite of the attention of the physics teaching profession in developing and publishing new demonstrations.[1] Indeed only three instructors employed brief demonstrations in the classes which were visited.

Table 22 lists certain teaching activities which were recorded by the researcher during each class visit. Two-thirds of the instructors appeared to follow the textbook closely. The textbook was used in two ways--as a course outline and as a source of problems. Principal deviations from the textbook by the instructor were to discuss material not covered in the text or to develop the material in a different way. Only one instructor recommended and required reading beyond the basic text.

The textbooks that were assigned for the courses visited are listed in Table 23. The textbook listed as No. 5 was used for the second semester of those courses that used No. 9 during the first semester. It was interesting to note that _none_ of the newly developed texts that were discussed in Chapter 1 (pp. 8-9) was used in any of the classes visited.

Problems were assigned or discussed in nearly half of the classes visited. In all, eighteen of the twenty-four instructors assigned problems during the periods visited. Some instructors devoted the entire period to discussing assigned problems.

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[1]A recent example of this interest is the AAPT sponsored reference, Harry F. Meiners, ed., _Physics Demonstration Experiments_, 2 vols. (New York: The Ronald Press Company, 1970).

All but two instructors used the chalkboard as their primary visual aid during the visits. The other two used the overhead projector with acetate overlays entirely in place of the chalkboard. Commercially or individually prepared transparencies were used by three instructors. One instructor used a pre-1940 16 mm. film to illustrate one topic.

Conclusions

The data gathered in this research reveal several important priorities held by instructors who teach introductory physics. These priorities are evident in both the statements of the instructors and from observations of their teaching practices. From the data gathered and discussed above one concludes that instructors of introductory physics:

1. believe that student mastery of the content of physics is the most important objective in the course which they teach.

2. believe that student mastery of the content of physics is the most important objective in the individual class periods.

3. believe that other objectives, particularly those dealing with the broader, cultural aspects of physics, to be of minimal importance.

4. employ lecturing and problem solution by the instructor, but mostly lecturing, as their primary teaching methods.

5. ask questions in such a way that a single response is expected or that the instructor himself answers the questions, i.e., primarily convergent or rhetorical questions.

6. ask questions which are the least intellectually demanding of the student, i.e., primarily knowledge and comprehension questions which require mainly recall to answer.

7. place primary importance upon written materials through reading

the textbook or working problems with minimum use of demonstrations or reference to the student laboratory.

The data gathered in this research have important implications regarding the status of the teaching of introductory physics. These data reflect the teaching objectives and practices of twenty-four instructors in six Oklahoma colleges and universities. The implications of these data, however, extend beyond these instructors and Oklahoma. Examination of the sources of the degrees of these instructors reveals that the combined degrees of all instructors (B.S., M.S., and Ph.D.) were received from twenty-eight separate colleges and universities. Of these colleges and universities, twenty-one were outside of Oklahoma. If it is true that teachers teach as they have been taught, then the kind of teaching which was observed in this research is not confined to those instructors and institutions that were visited.

These data also reveal that little effort has been expended in defining the course objectives for different groups of students. One questions whether the objectives suitable for physics majors and pre-engineering students should be the same, on the average, as those for pre-medical students or elementary school teachers. Similarly, are the teaching approaches--primarily lecture and example--suitable for all of the students enrolled in a course of introductory physics? The content of physics, studied in this way, is presented at a fairly high level of abstraction. The recent research by McKinnon and Renner has shown that a high percentage of entering college students do not think at an abstract level.[1] In view of that finding, what percentage of the students enrolled

[1]Joe W. McKinnon and John W. Renner, "Are Colleges Concerned with Intellectual Development?" American Journal of Physics, XXXIX (September, 1971), 1047-1052.

in the courses observed are truly profiting, intellectually, from this course in physics?

The absence of any noticeable differences in course objective preferences for different groups of students and the associated lack of differences in teaching practices leads to the conclusion that insufficient attention is given to determining the needs and capabilities of the students. Each of the instructors visited displayed evidence that he had made preparation for his class, and he solicited and answered questions from the students. However, his teaching was conducted in such a way as to demand only minimal involvement of the students. His teaching practices emphasized the highest ranked course objective, "an understanding of the basic concepts and principles of physics." However, the second highest ranked objective, "an understanding of physics as a process of inquiry," received little attention in view of the questions which the instructor asked. The instructor's emphasis in his teaching of physics was directed primarily toward the content of physics and far less toward the processes of physics which he, no doubt, practices in his own research.

Several instructors visited at length with the researcher about their course and displayed considerable interest in improving their teaching. One instructor, who had recently completed his Ph.D., confessed that he had had no teaching experience of any kind during his graduate studies. He noted that he had forgotten much of the content of the introductory course in the intervening years since he had taken it himself. His total experience, until this time, had been in research. His efforts to improve his own teaching consisted of informal discussions with the older instructors. There did not appear to be any routine process in which he could obtain assistance in better defining his own teaching goals or in improving his teaching methods.

Enrollments in physics and other sciences have been on the decline for some time. Friedenberg conducted a study in 1958-60 to find the reasons that college students left science as a career and changed to a different area of study. Among the conclusions which he drew from his study is this observation:

> Those of our best subjects who left did so because of the way scientists are taught and the way they are used; not because of what science essentially is. After all, it is our respondents who believe that science deals with deep and fundamental issues of being, who are correct. But undergraduates do not get much chance to get down to fundamentals.[1]

More recently Rigden has discussed the "noun" and the "verb" sense of physics. By the "noun" sense he means physics as a collection of laws, definitions and formulas; by the "verb" sense he means physics as a "dynamic discipline." He observes that, in spite of the newer physics curricula, "The introductory physics course remains, even in the newer versions, an attempt to confront the student with the totality of the subject. And the style in which the introductory course is taught has not changed."[2] He goes on to emphasize the need to ". . . place greater emphasis on the verb sense of science. . ."[3] The data gathered in this research confirm the "noun" status of physics teaching and support the almost total neglect of the "verb" aspect.

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[1]Edgar Z. Friedenberg, "Why Students Leave Science," Commentary XXXII (August, 1961), 154.

[2]John S. Rigden, "Reshaping the Image of Physics," Physics Today XXIII (October, 1970), 53.

[3]Ibid.

Recommendations

The primary responsibility of a college teacher is to teach. This responsibility implies far more than familiarity with ones subject. It also implies that the instructor should assess the objectives of his course in terms of their intellectual value to the student. Once these objectives have been established, the teacher must adapt his teaching methods in such a way as to attain his objectives. As a first start toward these ideals instructors have an obligation to familiarize themselves more thoroughly with the literature and research of physics teaching in particular and science teaching in general.

The research by McKinnon and Renner raises many questions as to the readiness of college students for the type of instruction which they receive in introductory physics. Their research revealed a highly significant number of students who increased in their level of abstract thinking as the result of enrollment in an inquiry-centered science course as compared to a group who had not been enrolled in this course. Would students enrolled in a physics course of the type observed in this present research show comparable improvements over a similar control group? Would these students show any differences from students enrolled in a course of the type described by McKinnon and Renner? Should such further study confirm the pessimistic conclusions which these researchers drew, teaching materials and teaching methods will have to be drastically revised if they are to be of value to many of the students who enroll.

Entire departments of physics should examine the objectives which they feel the introductory courses should emphasize. Once these goals are agreed upon by the instructors, experimental sections could be established to test different methods of teaching. Research which can establish a strong empirical base for the use of certain teaching methods is not something which can be ignored by departments of physics.

Are teaching practices, such as were observed in this research, prevalent in the teaching of the other sciences? The methods used in this research could be employed to determine the teaching practices in other science areas as well as in subject areas outside of science. Indeed, an individual instructor could easily check his own teaching practices and modify his teaching accordingly. Successful changes in teaching must, in the end, begin with each individual instructor.

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APPENDIX A
Exhibit 1

COURSE BACKGROUND

School_____________________________School Code_________Observation No._____

Instructor____Instructor Code_____

Rank of Instructor__________________Highest Degree of Instructor__________

Field of Highest Degree of Instructor_______________________________________

No. of Years Teaching____________No. of Years Taught Introductory Course____

Course No.______________Section No.______________No. Semester Hours_______

Course is designed for Science Majors_____; Liberal Arts Majors______; Pre-Professional Students, i.e., Pre-Meds., etc._____; All Students______; Engineering Students_____; Other_____, (Please Specify)_______________.

Number of Students____________

****

PURPOSES OF CLASS PERIOD

Please indicate by the number one (1) the item you feel most important as an objective of this period. Indicate by the number (2) the second most important objective, and so on. If you feel that any of these objectives has no application to this lesson, please indicate by NA.

_____To familiarize the student with the physical principles of the topic(s) of the lesson.

_____To provide the students with an opportunity to eveluate data or to draw conclusions based on physical data and/or principles.

_____To pose problems that require student action either through application of studied material or through laboratory activities.

_____To encourage the students to appreciate the usefulness of the physics discussed in this lesson in understanding the natural world.

_____To understand the value and application of mathematical formulation to physical problems.

_____To appreciate the historical development of physical theories.

_____Other (please specify) ____

____

APPENDIX A
Exhibit 2

PURPOSES OF COURSE Instructor Code_____

Following is a list of objectives that students might acquire from a study of introductory physics. Please indicate by circling the letter "M" those objectives which you believe are most important in this course; encircle "S" those objectives you believe have some importance; and encircle "N" those objectives that you believe have little or no importance to this course.

1. An understanding of physics as a process of inquiry. . . . . . M S N

2. An understanding of the basic concepts and principles of physics. . . . . M S N

3. Engender in the student a curiosity about the natural world . . M S N

4. An understanding of the importance of mathematical formulation of physical principles. . . . . M S N

5. An understanding of the historical development of physical concepts. . . . . M S N

6. An appreciation and understanding of the role of experimentation in physics. . . . . M S N

7. The importance of approaching problems outside of science with critical judgement. . . . . M S N

8. A tool for studies outside of physics, e.g., medicine. . . . . M S N

9. The relationship (and differences) between science and technology. . . . . M S N

10. An understanding of the limitations and changes of sciencific theories. . . . . M S N

11. The relationship between physics and other areas of science. . M S N

12. The relationship between physics and other areas of study, e.g., history, sociology, English, etc. . . . . M S N

13. An ability to understand and appreciate the goals and methods of current scientific research. . . . . M S N

14. Other (please specify)____________________________________

____

Please rank in descending order the numbers of those five (5) objectives you consider to be the most important in this course:________________
COMMENTS: (Please use back of sheet)

APPENDIX A
Exhibit 3

DEMONSTRATION CHECK LIST

Activity	Teacher	Student
Makes observations		
Relates problem to demonstration		
Analyzes data		
Asks questions		
Draws inferences		
Generalizes		
Hypothesizes		
Suggests further activities		

Observation # ________

Subject of demonstration____

Technical quality of demonstration

A. Suitability____

B. Visibility____

C. Definiteness of results____

Length of time devoted to demonstration and discussion__________________

APPENDIX A
Exhibit 4

Observation #______

CHECK LIST OF INSTRUCTOR ACTIVITIES

Text:____Text pages:______

Topic:____

Instructor:

1. Followed the text closely: _____yes; _____no

2. Diverged substantially from the text:_____yes; _____no

3. Used appropriate visual aids: ____yes; ____no

4. Employed appropriate demonstrations: _____yes; _____no
(If "yes", refer to "Demonstration Check List".)

5. Recommended appropriate outside reading: _____yes; _____no

6. Required appropriate outside reading: _____yes; _____no

7. Problem assignment: _____yes; _____no

8. Referred to previous laboratory work: _____yes; _____no

9. Referred to future laboratory work: _____yes; _____no

10. Teaching method (% of time: Lecture_____; Discussion_____
Demonstration______

OBSERVER'S COMMENTS:

APPENDIX A
Exhibit 5

INSTRUCTOR QUESTION CHECKLIST

Purpose of Question \ Type of Question	Directive	Leading	Divergent	Convergent	Rhetorical	Total
Knowledge						
Comprehension						
Application						
Analysis						
Synthesis						
Evaluation						
Opinion						
Total						

LECTURE EMPHASIS

	Time (Min.)	% Total Time
Description or qualitative explanation of concepts or principles		
Working problems or examples		
Derivation of formulas		
Demonstrations		
Total		100

APPENDIX B

THE TRANSFORMATION FROM NATURAL PHILOSOPHY
TO PHYSICS IN COLLEGE TEACHING PRACTICES
SINCE THE SEVENTEENTH CENTURY[1]

Teaching practices in American colleges have undergone a continuous evolution since the first colleges were established in the seventeenth century. Changes can be observed in both the purposes and the methods in college teaching, as well as in the curriculum. Historian Samuel Eliot Morison has noted that the model of Harvard's founding in 1638 was basically British. The New England puritans carried with them an intellectual tradition that had its roots in the University of Cambridge.[2] Indeed, the town in which their new college was to be built was named "Cambridge."

The curriculum was designed to produce an educated gentleman. While the colonial colleges trained ministers, they were not solely theological seminaries.

All students, whether or not candidates for the pulpit, took a pre-

[1]Charles Weiner has examined the role of society on the introduction of science in higher education in his essay, "Science in the United States," in Science and Society in the United States, ed. by David D. Van Tassel and Michael G. Hall (Homewood, Ill.: The Dorsey Press, 1966), pp. 163-189.

[2]Samuel Eliot Morison, The Intellectual Life of Colonial New England, Great Seal Books (Second ed.; Ithaca, N.Y.: Cornell University Press, 1956), pp. 18-20.

> scribed course in six of the traditional Seven Arts (Grammar, Logic, Rhetoric, Arithmetic, Geometry, and Astronomy), in the Three Philosophies (Metaphysics, Ethics, and Natural Science), and in Greek, Hebrew, and Ancient History. Latin was supposed to have been mastered in grammar school; it was the language of instruction, and of most of the textbooks.[1]

Instruction in the new colleges was conducted primarily by tutors, who for the most part, were only recently graduated from college. The tutors, often transient in their period of service, were not outnumbered by a regular faculty until well into the eighteenth century.[2] Andrew Dickson White, first president of Cornell, notes that during his studies at Yale as late as 1850

> The president and professors were men of high character and attainments; but to the lower classes the instruction was given almost entirely by tutors, who took up teaching for bread-winning while going through the divinity school. Naturally most of the work done under these was perfunctory.[3]

Natural philosophy, from which physics and chemistry were to evolve during the nineteenth century, was Aristotelian. When studied at all, natural philosophy was studied as a part of philosophy and by the methods of philosophy.[4]

> The methods employed in class were to read the text, and to outline, discuss and dispute the principles contained in it. At graduation some of these principles might be used as theses to be defined or refuted according to the rules of syllogistic argument.[5]

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[1] Ibid., p. 42.

[2] Russel Blaine Nye, The Cultural Life of the New Nation: 1776-1830, The New American Nation Series, Harper Torchbooks (New York: Harper & Row, Publishers, 1960), p. 172.

[3] Andrew D. White, Autobiography of Andrew D. White (New York: The Century Co., 1904), I, 26.

[4] John J. McCarthy, "Physics in American Colleges Before 1750," American Journal of Physics, VII (April, 1939), 100.

[5] Ibid., p. 101.

The publication of the first edition of Newton's Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy) in 1687 and the subsequent publication of his Opticks in 1704 introduced new dimensions into the methods of natural philosophy. The methods displayed in each of these works are noticeably different. The Principia is a model of strict mathematical deduction from basic postulates. The Opticks, on the other hand, is characterized by its emphasis on the empirical approach. Newton's works, along with the Royal Society's publication, Philosophical Transactions, soon had great influence in replacing the Aristotelian approach to natural philosophy.[1]

The changes taking place in natural philosophy were also affecting its teaching. In 1687 Charles Morton's Compendium Physicae was adopted by Harvard and was used there for nearly forty years. It contained much material on the experimental methods which were being espoused by the Royal Society.[2] There is evidence that Aristotelian natural philosophy was being replaced in the other Colonial colleges, so that by the mid-eighteenth century the transition to Newtonian philosophy was essentially completed.[3]

The classical emphasis of the colonial college remained, although instruction in natural philosophy was not neglected. Scientific instruments were acquired by Harvard, beginning with the presentation of a

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[1] A detailed discussion of Newtonian philosophy in the eighteenth century is given in I. Bernard Cohen, Franklin and Newton, Memoirs of the American Philosophical Society, Volume 43 (Cambridge, Mass.: Harvard University Press, 1956).

[2] Theodore Hornberger, Scientific Thought in the American Colleges: 1638-1800 (Austin: The University of Texas Press, 1945), p.40.

[3] Ibid., pp. 57-69.

telescope by Governor John Winthrop in 1672. Thomas Hollis endowed a chair for a "Professor of Mathematics and Natural Philosophy" in 1727 and contributed a substantial number of scientific instruments. These instruments and other which had been collected by the college were destroyed by fire in 1764.

However, within 15 years after the fire Harvard had assembled a new collection ". . .which in scope, variety, and quality far surpassed that consumed in the Fire. It must have been a deep-seated conviction of the value of the sciences that spurred on the members of the Harvard community to repair that great loss in so short a time."[1]

Natural philosophy was not neglected at the other Colonial colleges. Appointments of professors of natural philosophy and lists of course requirements indicate that natural philosophy was taught in some way at William and Mary, Yale, Brown, the University of North Carolina, Dartmouth, Pennsylvania, and Columbia, all before 1800.[2] What is not clear, however, is the amount of actual time or the manner of instruction that was devoted to natural philosophy in these early colleges, even though various courses are listed in the college records.

While the Colonial college had a responsibility in the training of ministers, the study of natural philosophy was considered as an important part of this training. Cotton Mather gave strong encouragement for the study of natural philosophy in his outline of studies, Manuductio ad Ministerium, Directions for a Candidate of the Ministry (Boston, 1726). He emphasized that this study was not to be of Aristotle, and he urged

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[1] I. Bernard Cohen, Some Early Tools of American Science (Cambridge, Mass.: Harvard University Press, 1950), pp. 9-10.

[2] Hornberger, Scientific Thought, pp. 25-34.

students to gain ". . .as thorough an Insight as you can get into the Principles of our Perpetual Dictator, the incomparable Sr. Isaac Newton, is what I mightly (sic) commend unto you."[1]

Commenting on the manuscripts of the lectures of Professor John Winthrop and of his successor, Samuel Williams, historian I. Bernard Cohen notes:

> They are far from being dull. Not only were they enlivened by experiments performed with the instruments in Harvard's Apparatus, but they continually evoked references to the applications of scientific principles to the affairs of daily life and discussions of the larger questions concerning the ultimate source of things and primary causes.[2]

He goes on to indicate, however, that this means of teaching was somewhat unique.

> Contrasted with the method of studying Locke, in which the students were required to "commit whole paragraphs to memory, and to repeat them to the tutor," the lectures on natural philosophy stand out as bright lights in 18th-century education at Harvard. Whereas the method of memorizing sections of An Essay Concerning Human Understanding "saved both the tutor and scholar the trouble of thinking, --one to ask and the other to answer questions on the author's doctrines," the science professor encouraged the students to come to him with their questions.[3]

It appears that demonstrations were not uncommon in classes on natural philosophy at other colleges. A study of the notes of the lectures of Bishop James Madison taken by Robert D. Murchie, a student at William and Mary in 1809, illustrates this and indicated some of the topics which were included.

> There are numerous instances in these notes where it is quite apparent that demonstrations were performed by the lecturer.

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[1]Cohen, Tools of American Science, pp. 11-12.

[2]Ibid., p. 14.

[3]Ibid., p. 15.

> These include experiments in magnetism, the guinea and feather tube, electrostatic experiments using a friction machine, Torricellian vacuum, candle in a vacuum, reflection of heat, and the preparation of "nitrous air" from nitric acid and iron.[1]

Changes in curriculum and methods of teaching evolved slowly in the 19th century college. Emphasis remained with the classical curriculum. In natural science, lecturing and some class demonstration was beginning to replace the drill and recitation of the tutor in a few colleges. Any detailed study of nature or nature's laws by student observation or experimentation, however, was still an extracurricular activity.[2]

In March, 1817 Amos Eaton began a course of invited lectures in Natural History at Williams College. Eaton wrote in 1832:

> . . . I was able to commence my course of instruction to good advantage, considering the low state of the Science in this country. Such was the zeal at this institution, that an uncontrollable enthusiasm for Natural History, took possesion of every mind; and other departments of learning were, for a time, crowed out of College. The College authorities allowed twelve students each day (72 per week) to devote their whole time to the collection of minerals, plants, &c. in lieu of all other exercises.[3]

In spite of this support Eaton's field trips were still outside the bounds of the formal curriculum.[4]

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[1]Galen W. Ewing, "Early Teaching of Science at the College of William and Mary in Virginia," Journal of Chemical Education, XV (January, 1938), 9.

[2]Frederick Rudolph, The American College and University: A History, Vintage Books (New York: Alfred A. Knopf, Inc. and Random House, Inc., 1965), pp. 223-228.

[3]Amos Eaton, Geological Text-Book, for Aiding the Study of North American Geology (2nd ed; Albany: Websters and Skinners; New York: G. and C. and H. Carvill; and Troy: William S. Parker, 1832), p. 16.

[4]Frederick Rudolph, Mark Hopkins and the Log: Williams College, 1836-1872, Yale Historical Publications, Miscellany 63 (New Haven: Yale University Press, 1956; London: Geoffrey Cumberlege, Oxford University Press, 1956), pp. 138-139.

Eaton's use of the natural environment to study botany and mineralogy at Williams, and later, as first "Senior Professor and Agent" at Rensselaer, contributed to his reputation as a scientist and teacher. Indeed the pioneering activities of Eaton and his role in the formation of Rensselaer should not be minimized. "The Rensselaer School" was incorporated in 1826 and was based on Eaton's ". . .plan of experimental education with individual laboratory experimentation by the students. . . ."[1] Under this plan Eaton established separate departments of the natural sciences complete with their own laboratories and established ". . .his practical plan of teaching human beings to learn by doing."[2] In these efforts Eaton pioneered " . . .in teaching classes by making his pupils experimenters and workers in every department of science where it was practicable; substituting also lectures by the pupils to each other in place of the usual system of recitations.'"[3] While the Rensselaerean plan of Eaton received much praise from Eaton's contemporaries, there seems to be little indication that it was widely imitated.

Another important pioneering professor of the early 1800's was

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[1]Ethel M. McAllister, Amos Eaton (Philadelphia: University of Pennsylvania Press, 1941; London: Humphrey Milford: Oxford University Press, 1941), p. 383.

[2]Ibid.

[3]Calvin Durfee, A History of Williams College (Boston: A. Williams, 1860), quoted in Palmer C. Ricketts, History of Rensselaer Polytechnic Institute: 1824-1914 (New York: John Wiley and Sons, 1914; London: Chapman & Hall, Limited, 1914), p. 27.

Joseph Henry. Henry was professor of mathematics and natural philosophy at Albany Academy from 1826 to 1832. During this time he met and formed a friendship with Eaton. This friendship undoubtedly let to Eaton's recommendation of Henry as one of Rensselaer's examiners in mathematics. It is also likely that Eaton had some influence on Henry's ideas on education.[1]

Henry moved from Albany Academy in 1832 to become a professor of natural philosophy at Princeton. Here Henry extended and expanded his experimental research in electromagnetism, which he had begun at Albany. Much of this research was closely related to his teaching responsibilities, which he took very seriously. Often he undertook investigations designed to clarify his own ideas on a subject so he could present it accurately to his classes.[2] In particular his pioneering research in electricity and electromagnetism was introduced to his classes as his research progressed. By the time he left Princeton in 1846 his reputation as a researcher as well as a lecturer was assured.

It would not be unfair to say, however, that most of the teaching practices in the American colleges were, at best, unimaginative well into the 19th century.

> Most teaching was done by the recitation method (occaisonally be lecture or demonstration), in which the student studied a text, memorized it, was drilled on it, recited it, and was checked by the

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[1]Thomas Coulson, Joseph Henry: His Life and Work (Princeton, N.J.: Princeton University Press, 1950; London: Geoffrey Cumberlege, Oxford University Press, 1950), pp. 18-19. Henry's ideas on education were not published until much later. See Joseph Henry, "Introductory Discourse: Thoughts on Education," The American Journal of Education, I (August, 1855), pp. 17-31.

[2]Charles Weiner, "Joseph Henry and the Relations between Teaching and Research," American Journal of Physics, XXXIV(December, 1966), 1096.

teacher for correctness. . .There was little time for discussion and whatever original thinking the student did was usually on his own time.[1]

Andrew Dickson White, a member of the Yale class of 1853, commented on the type of instruction that he received.

The worst feature of the junior year was the fact that through two terms, during five hours each week, "recitations" were heard by a tutor in "Olmsted's Natural Philosophy." The text-book was simply repeated by rote. Not one student in fifty took the least interest in it; and the man who could give the words of the text most glibly secured the best marks. One exceedingly unfortunate result of this kind of instruction was that it so disgusted the class with the whole subject, that the really excellent lectures of Professor Olmsted, illustrated by probably the best apparatus then possessed by any American university, were voted a bore.[2]

There were, of course, other notable exceptions to the type of drudgery described by White. At Williams College Mark Hopkins earned a well deserved reputation for his manner of instruction, as well as his other influences on education.

"What do you think?" was the disarming and at that time unique question with which he frequently punctuated his classes. Students, unaccustomed to being asked what they thought, experienced a sense of growth merely in the presence of the question. Furthermore, Hopkins did not insist that students agree with him. He did not care whether they had paid much attention to the textbook or whether they had committed any of it to memory. He did not push abstruse points to their fullest refinement, preferring to deal in generalities which would leave his students free to explore for the refinements themselves. He introduced a bit of novelty into his teaching by pioneering in the use of visual classroom aids: in 1841 he enlivened his discussion of anatomy with a lifesize model of a man made by the French physician, Louis Auzoux. In 1845 he added a skeleton to his classroom equipment, and in the 1870's he began to make extensive use of the blackboard to illustrate the main outlines of his "moral system."[3]

Hopkins' reputation as a teacher, however, was unique even at

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[1]Nye, Cultural Life, p. 184.

[2]White, Autobiography, I, pp. 27-28.

[3]Rudolph, Mark Hopkins, p. 50.

Williams. Inexperienced tutors still conducted the lower level instruction. Their methods of instruction, as well as those of their senior colleagues, showed little reflection of Hopkins' example. Professorships were filled largely by the appointment of Williams alumni, and more attractive salaries elsewhere did not lead to the development of the best faculty.[1]

The changes taking place in American culture were also affecting higher education. Among these influences was the gradual influx of the German-educated professor. Among the first American professors to study in Germany was George Ticknor who resided at Gottingen for twenty months between 1815 and 1817. Ticknor soon noted some basic differences between the American college and the German university. Writing to a friend in 1816 he decried the poor library collection at Harvard as contrasted to Gottingen.

> I cannot better explain to you the difference between our University in Cambridge and the one here than by telling you that here I hardly say too much when I say that it consists in the Library, and that at Cambridge the Library is one of the last things thought and talked about,--that here they have forty professors and more then two hundred thousand volumes to instruct them, and in Cambridge twenty professors and less than twenty thousand volumes.[2]

Ticknor earlier had written Thomas Jefferson, praising the enthusiasm of the German professor, his scholarly freedom, his level of scholarship, and the importance which he paid to publication of his researches.[3]

While at Gottingen Ticknor was offered the newly founded Smith

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[1] *Ibid.*, pp. 53-54.

[2] George Ticknor to Stephen Higginson, Gottingen, May 20, 1816, in *American Higher Education: A Documentary History*, ed. by Richard Hofstadter and Wilson Smith, Phoenix Books (Chicago and London: The University of Chicago Press, 1961), I, 256.

[3] George Ticknor to Thomas Jefferson, Gottingen, October 14, 1815, *Ibid.*, pp. 257-258.

Professorship of French and Spanish Languages and professor of belles-lettres at Harvard. His tenure at Harvard--dating from 1819 to 1835--was marked with frustration in attempting to adapt Harvard to the model of the German university. He met with limited success only in his own department with the offering of courses of an advanced nature.[1]

Thwing, in his study of the influence of the German university on American higher education, notes that by the first half of the nineteenth century less than two hundred American students had been matriculated at German universities.

> In the fifth decade, the number came to exceed one hundred, and in the sixth, it increased at least three-fold. In the seventh, American students again increased three-fold, passing beyond a thousand. In the eighth, they enlarged by a small proportion above the one-thousand of the preceding period. In the ninth decade, they touched their highest mark, exceeding two thousand. . . .[2]

James Morgan Hart, a graduate of the College of New Jersey was a student at Berlin, Geneva, and Gottingen from 1860 to 1864. Upon his return to the United States he wrote of his experiences as a student in the German university. Hart notes in his Preface that while

> . . .holding that the German method of Higher Education is far above our own, I should be very sorry to see that method adopted at once, and in the lump. Before taking decided steps towards the expansion of our colleges into quasi universities, it will be advisable for us to consider thoroughly what a university really is, what it accomplishes, what it does not accomplish, the basis upon which it rests, the relations that it holds to the nation at large. Until we have formed clear and stable conceptions upon all these points, innovation, I fear, will be only tinkering, not reform.[3]

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[1]Rudolph, The American College, pp. 118-119.

[2]Charles Franklin Thwing, The American and the German University (New York: The Macmillan Company, 1928), p. 42.

[3]James Morgan Hart, German Universities: A Narrative of Personal Experience (New York and London: G. P. Putnam's Sons, 1874), p. vii.

Hart goes on to spell out some of the unique characteristics of the German university. These are the object of study--Wissenschaft--and the conditions of study--Lehrfreiheit and Lernfreiheit.

> By Wissenschaft the Germans mean knowledge in the most exalted sense of that term, namely, the ardent, methodical, independent search after truth in any and all its forms, but wholly irrespective of utilitatian application. Lehrfreiheit means that the one who teaches. . .is free to teach what he chooses, as he chooses. Lernfreiheit or the freedom of learning, denotes the emancipation of the student from Schulzwang, compulsory drill by recitation.[1]

He goes on to observe that the chief task of German university instruction, ". . .that to which all its energies are directed, is the development of great thinkers, men who will extend the boundaries of knowledge."[2]

It is clear that the German professor was, by necessity, a specialist in his field. In contrast, his American counterpart was often called upon to teach the whole range of college subjects. Thus, natural science, as taught in Germany, was rapidly being divided into the specialties of physics, chemistry, and biology. Another difference in the attention paid to the natural sciences is observed by Thwing. He notes the fact that ". . .scientific research in Germany is conducted, usually, --not always,-- in the university. In England it is conducted, usually,--not always,--in private laboratories, or in royal or similar institutions."[3]

As a result of the influence of German scholarship, a different dimension and concept of nineteenth century science was obtained by those who studied in the German university. The German-educated professor would no longer be satisfied merely with teaching a wide range of subjects.

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[1] Ibid., p. 250.

[2] Ibid., p. 259.

[3] Thwing, The American and the German University, p. 171.

His teaching interests would be specialized, and he would have greater interests into deepening his own understanding of his specialty by research. Professors, imbued with these ideas, would meet with frustration in many American colleges which were slow to adapt to the changes which these ideas implied.

It was inevitable that the influences of the German university education on an increasing number of American students would eventually begin to have their effects on American higher education. The early Colonial (and English) ideal of higher education--the production of an educated gentleman--would eventually be modified as the newer ideas of higher education were introduced into the American college. The gradual end result, however, would not be the mere transplanting of the German university in America, but would result in a new kind of institution which would be distinctly American.

Other cultural changes had also been taking place for some time which were having their effects upon the American college. The recognized need for educated specialists--engineers, teachers, agricultural experts, and manufacturers--had led to the establishment of Rensselaer in 1826. Under Amos Eaton's guidance, laboratory instruction was first introduced in physics and chemistry, and the first engineering degree was awarded in 1835.[1]

Changes in the older colleges were slower in coming. The Yale College catalogue of 1845 indicates that the first two years were devoted to Latin, Greek, and mathematics. Only in the junior year was there ". . .one course in science extending through the year, viz., natural

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[1]Rudolph, The American College, pp. 229-231.

philosophy dealing with mechanics, hydraulics, electricity, optics, etc."[1] The situation was little different at Harvard, Williams, College of New Jersey, Columbia, and the University of Virginia.[2] It is true that Benjamin Silliman, Sr. had been conducting experiments in chemistry at Yale as early as 1817, but he did not encourage student participation. While he had a few special assistants, he commented that students ". . .might come and see what we were doing, and I should much prefer that they should do nothing; for then they would not hinder me and my trained assistants, nor derange or break the apparatus."[3] Indeed the laboratory was a personal one, equipped at Silliman's own expense. As late as 1842, Benjamin Silliman, Jr. obtained a private room at Yale where a few students could be instructed, but this still had no official connection with the college.[4]

It is clear that science, as it was taught in the colleges in the mid-nineteenth century, was simple and elementary. Instruction

> . . .was limited to text-book work, supplemented by lectures with some demonstrations. Laboratories, as we know them today, did not exist. . . . Anything approaching laboratory work by students, the actual carrying out of an experiment or making an observation, was not even thought of, for as a matter of fact at that date very few even of the professors holding chairs in the sciences possessed the necessary equipment, or had the requisite rooms for much, if any, experimental work.[5]

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[1]Russell H. Chittenden, History of the Sheffield Scientific School of Yale University: 1846-1922 (New Haven: Yale University Press, 1928; London: Humphrey Milford: Oxford University Press, 1928), I, 21-22.

[2]*Ibid.*, pp. 23-25

[3]Dirk J. Struik, Yankee Science in the Making (Boston: Little, Brown and Company, 1948), p. 339.

[4]*Ibid.*, p. 340.

[5]Chittenden, History of the Sheffield Scientific School, I, p. 26.

Changes were also slowly affecting Harvard. In February of 1847 "The Scientific School of the University at Cambridge" was established by the Harvard Corporation to provide instruction in science and engineering. With the donation of $50,000 by Abbott Lawrence in June of the same year the new school was promptly renamed the "Lawrence Scientific School in the University at Cambridge." The classical requirements of Harvard College were abandoned in the new School; subjects of mathematics, chemistry, experimental philosophy (physics), and engineering took their place.[1] In the early days of the Lawrence School good teachers were obtained, and ". . .instruction was intimate, personal, and inspiring. The facilities for teaching the physical sciences and Civil Engineering were good, and for natural science they were unrivalled."[2] Changes in instructional methods were dramatic. They included laboratory exercises in the various sciences as well as field experience in surveying and trips to various "manufacturing establishments."[3]

At the same time Yale was slowly moving toward the development of a scientific school. The School of Applied Chemistry was established in 1847 in the new Department of Philosophy and the Arts. Classes were opened to students, primarily in chemistry, in the fall of the same year.[4]

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[1]Hector James Hughes, "Engineering And Other Applied Sciences in the Harvard Engineering School and its Predicessors, 1847-1929," in the Development of Harvard University Since the Inauguration of President Eliot: 1869-1929, ed. by Samuel Eliot Morison (Cambridge, Mass.: Harvard University Press, 1930; London: Humphrey Milford: Oxford University Press, 1930), pp. 413-417.

[2]Ibid., p. 417.

[3]Ibid., pp. 417-418.

[4]Chittenden, History of the Sheffield Scientific School, I, pp. 41-42.

> The instruction they received was radically different from the usual type of college classroom work. It was mainly personal contact in the laboratory. . . .In a sense, each man was an investigator, feeling his way carefully along paths which were unfamiliar, gaining strength and confidence as he progressed, and acquiring habits of self-reliance and the power of drawing sane and safe deductions from observed facts. The professor and his assistant were there to guide and advise, not to drive along an unattractive path, and hence there was engendered a freedom of thought and action conducive to mental independence. This laboratory practice naturally adapted itself to the specific needs of the individual, and consequently with a group of a dozen or more men, various phases of work were in progress from which all could derive some benefit.[1]

In 1858 Joseph E. Sheffield donated an enlarged and refitted building and equipped it for use as a scientific school. The Yale Corporation, in appreciation, named this the Sheffield Scientific School in 1861.[2] A Professorship of Industrial Mechanics and Physics was established in 1859.[3]

The idea of the scientific school soon spread to other colleges. During the 1850's scientific departments of some kind were established at

> . . .the University of Rochester, Denison, the University of Michigan, Illinois College, the University of North Carolina, New York University, the State University of Iowa, and the University of Missouri. Between 1860 and 1870 at least twenty-five institutions would open scientific departments.[4]

The new science curriculum was not meant to replace the classical studies of the traditional B. A. degree; the new studies were a separate adjunct to the college. Harvard avoided a possible compromise of its B. A. degree by creating the Bachelor of Science degree in 1851; Yale

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[1] Ibid., p. 49.

[2] Ibid., p. 77.

[3] Ibid., p. 77.

[4] Rudolph, The American College, pp. 232-233.

began the degree of Bachelor of Philosophy in 1852. The new degrees were not held to be equivalent to the old B. A. degree, however. Admission requirements were reduced, and the length of study was reduced from four to three years. Students in the scientific school were often looked down upon. "At Yale, for instance, Sheffield students were not permitted to sit with regular students in chapel."[1]

While the new Lawrence and Sheffield schools served a need for more intensive scientific education than had been available, the established traditions of the parent college did not encourage them as equal educational partners. Many years earlier Rensselaer had pioneered as a scientific and engineering college in its own right, but it had remained alone in its efforts. Now a number of German professors were beginning to emigrate to the United States, and a number of American professors were returning from advanced studies at German universities. These professors, imbued with the philosophy of German higher education, were restless to change the curriculum and teaching methods of the traditional American college. The lethargy of the older colleges in adapting to these views encouraged the establishment of new colleges--colleges not committed to the traditional values or methods.

Massachusetts Institute of Technology was one of these. M.I.T. was incorporated by the State of Massachusetts in 1861 and organized in 1862. Classes were opened for students in the School of Industrial Science in 1864. Under the leadership of its first president, William Barton Rogers, laboratory instruction became an integral part of the new curric-

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[1] Ibid., p. 232.

ulum.[1] Early instruction in physics was primarily by lecture, recitation, and demonstrations. However, Professor Edward Pickering introduced laboratory instruction in introductory physics by 1869. This was expanded into the advanced courses, and students were required to complete laboratory investigations for a graduating thesis.[2]

The ideals of science, research, and the German university tradition came to full fruition in 1876 with the founding of Johns Hopkins University. The new university reflected a variety of teaching methods along with its expanded curriculum. Traditional recitations were used to some extent, and demonstrations in science ". . .were carefully adapted to bring instruction rather than amazement."[3] Field trips in various subjects were common. The lecture, while not unknown in the older colleges, began to play a more important role. G. Stanley Hall, professor of psychology and pedagogics, considered lecturing novel enough to consider it as a recommendation that he had taught by this method. Lecturing was also used in chemistry and physics. Remsen's lectures in chemistry delivered with few notes, were long remembered for their clarity. Rowland, on the other hand, merely read his physics lectures from notes prepared for the three year cycle of courses.[4]

Laboratories received a place of eminence in beginning and advanced

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[1]Silas W. Holman, "Massachusetts Institute of Technology," in History of Higher Education in Massachusetts by George Gary Bush, No. 13 of Contributions to American Educational History, ed. by Herbert B. Adams (Washington: Government Printing Office, 1891), pp. 280-298.

[2]*Ibid.*, pp. 304-305.

[3]Hugh Hawkins, Pioneer: A History of the Johns Hopkins University, 1874-1889 (Ithaca, N.Y.: Cornell University Press, 1960), p. 220.

[4]*Ibid.*, pp. 221-222.

courses alike. Unique at Johns Hopkins, and a further influence of the German university, was the seminar. Through seminar instruction students were able to study at the frontiers of knowledge and, perhaps more important, receive training in the methods of research.[1]

The teaching practices in American colleges have undergone a slow evolution. From the preceding discussion it is clear that these changes have been associated with the institutions and the cultural influences which have affected them. The early emphasis on drill and recitation that was prevalent for so long was gradually modified. The study of natural philosophy, for example, let to the usefulness of demonstrations to illustrate the subject under discussion. The inclusion of the laboratory as even a desirable means of instruction was much slower. Although the laboratory had become an accepted part of science instruction by the end of the 19th century, it had no large body of tradition to support it. Indeed, Arthur G. Webster, writing in 1892, commented that

> . . . physical laboratories are decidedly new affairs. I believe it would be no exaggeration to say that twenty years ago there was not in this country a single building devoted solely to the purposes of a physical laboratory. Most of the large college laboratories have been erected within the last ten years. . . .[2]

However, by the turn of the century the student laboratory, along with lectures and demonstrations were becoming a fairly standard method of physics teaching in the majority of American colleges. This method has not been substantially modified since that time.

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[1] *Ibid.*, pp. 224-231.

[2] Arthur G. Webster, "A National Physical Laboratory," *The Pedagogical Seminary*, II (1892-93), 91.