AN INTEGRATION OF HISTORY AND DEMONSTRATIONS OF PHYSICS INTO THE INTRODUCTORY PHYSICS COURSE

by

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B.Sc., Ho Chi Minh University, 1981

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE in the Faculty of Education

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ABSTRACT

This study explores an approach to teaching introductory physics which draws on the history of science and the use of demonstrations. This approach is an attempt to make introductory physics more interesting and meaningful to students, to challenge the reputation that physics is merely mathematics exercises or analyses. The study investigates an introductory physics course in Vietnam which included a case history and eight physics demonstrations. Student seminars were used for the case history and a learning cycle was suggested for the demonstrations. The teaching approach was designed to improve students' attitudes and understanding of physics.

The content of the study focuses around molecular and thermal physics in a class of sixty students at Nhatrang University of Fisheries in Vietnam. Two other classes of the university were involved as the control groups. Two tests, one survey and a faculty discussion are the data sources for the study. Both quantitative and qualitative research techniques are used for data analysis.

The data analysis shows increases in students' interest and motivation toward the course and teaching approaches that were used. The promotion of students' physics understanding is reflected through the survey, but achievement tests do not show clear results. Discussion of the faculty gives strong support for the program, culminating in an agreement to broaden the program to other content areas of the introductory physics course.
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Finally, my thanks to all my students and colleagues at Nhatrang University of Fisheries without whose participation and encouragement this study would not have been possible.
DEDICATION

To my parents, Le Van Hoa and Cao Thi Em, who have devoted their lives to my studies.

And to my wonderful wife, Hoang Anh, who has made many sacrifices over the last three years so that I could reach this day.
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Chapter 1

The Setting and the Problem

Need for education reform in Vietnam

Following the reunification of Vietnam in 1975, massive changes have occurred in the country’s educational system. In 1990, the former Ministry of Education, the General Department for Vocational Training, and the Ministry of Higher and Secondary Technical Education were fused together as one “Ministry of Education and Training” (Bo Giao Duc va Dao Tao). The first five years after reunification were also marked by a severe shortage of well qualified people in the general work force, poor economic conditions, and very few resources for education (World Education Service, 1994). The Government has undertaken enormous efforts to alleviate illiteracy, yet there remain some persistent problems in the remote mountain areas and in the Mekong Delta area, where there are inadequate schools and a shortage of teachers.

The national initiative to upgrade the educational system led to the development of a plan in 1990 to re-structure post-secondary science education in Vietnam, and to the formation of a consortium of eleven universities to undertake science curriculum development and teacher education. The broad intention of this plan is to establish a “University Credit System,” which includes two phases of work for undergraduate students of science. The first phase is a “basic science” component, the General Higher Education Phase, which will be taught in community colleges across the country. After two years of study in this phase, students will transfer into university for the second phase of their education—the Specialized Higher Education Phase. This University Credit System will thus enable improved access to a basic science education, particularly in the
more remote areas of the country, and a solid foundation for further study of science in applied contexts.

While the broad purpose for this restructuring is to increase access to basic science education, and, therefore, to improve the scientific and technological literacy of the Vietnamese citizenry, there are many problems and conditions that help to shape the specific nature of the impending reform. The country has been somewhat isolated from the professional science and science education communities for the past twenty years, and textbooks and teaching methods reflecting current understandings in science are lacking. The condition of teaching laboratories is very poor in certain areas of the country, and this, in part, has led to a rather "rhetorical" science education, that is, one which relies heavily on rote memorization and routinization, at the expense of "broad and deep understanding" of the subject matter—the fundamental principles of science. Frequently, the need to learn by memorization is exacerbated by the lack of practical, concrete laboratory activities that are relevant and motivating for students.

These impoverished conditions for university science education and the need for reform underscore the need to examine the purposes of science education. There is a need to develop a science curriculum and program of studies that reflect the true nature of the scientific enterprise, the inter-relations among science, technology, and society, as well as the historical and philosophical bases for scientific theories and achievements.

Context of the problem

The use of the history of physics in physics teaching is not a new approach. It was a focus of several international conferences on physics education sponsored by the International Commission on Physics Education (ICPE) held in Rio de Janeiro (in 1963), Zurich (in 1967) and in Cambridge, Massachusetts (in 1970). The first International Conference about The History and Philosophy of Science in Science Teaching was also
held in Florida State University (in 1989). In the Report on the Recommendations of the
International Working Seminar on The Role of the History of Physics in Physics Education
at the Massachusetts Institute of Technology (MIT) in 1970, the Seminar requested:

(a) The seminar requests that the International Commission on Physics Education inform national authorities concerned with physics education of the activities of the seminar and that they encourage these bodies to establish mechanisms to allow and to encourage teachers of physics at all levels to use historical materials in their courses, in general accordance with the aims and goals in the seminar report.

(b) It is further requested that the commission encourage agencies and institutions responsible for the education (including refresher education) of those who teach physics, both at the secondary school and college level, to include training in the use of historical materials in their teacher preparation programs. At a first approximation, it is suggested that at least one course in the history of science focusing on the history of physics and an introduction to the case study method is essential if teachers are to be adequately equipped to use historical materials in their own classrooms.

(Brush & King, 1972, p. 91)

The first significant development of a historical approach in science education began at Harvard University (United States) in the late 1940’s under the leadership of President James B. Conant. Klopf er and Watson (1957), in Historical Materials and High School Science Teaching, extended the case history idea by developing cases for use by high school students. During the 1960’s, The Project Physics Course was developed at Harvard with significant amounts of historical material and it contributed a vast amount of experience in bringing history into the teaching of physics. Conant (1957) edited eight case histories into the two-volume Harvard Case Histories in Experimental Science. These cases “are one of the most convenient starting points for a serious venture into the history of science” (Russell, 1981, p. 52).

An historical approach in physics teaching is expected to contribute to physics education in many ways. Conant (1947), and Brush (1969, 1974, 1989) focus on having students understand the methods of science; Cohen (1950) believes history makes science lectures “richer and more profound and of greater interest” (p. 358) to students; Klopf er
(1969) believes the history of science contributes to students' scientific literacy; Russell (1981) emphasizes the role of history in improving students' attitudes toward science and their understanding of the methods of science; Sequeira and Leite (1991) believes that "the teachers' knowledge about the history of science can promote the students' conceptual change" (p. 53) in science teaching. Quattropani (1978) concludes that an historical approach to science could be a method of increasing student understanding of the relationships among science, technology and society. This review is continued in more depth in Chapter Two.

The declining of the number of students majoring in physics and the large number of non-major physics students in almost any introductory physics course nowadays also reminds us to find out an appropriate approach to physics teaching:

Everyone in the profession of teaching physics knows that the number of students actually majoring in physics has been decreasing. Most of the readers of this journal undoubtedly deplore this trend, but unless and until we can find more money for science education and more jobs for scientists and science students, there is little we can do about these declining enrollment figures. Physicists will therefore have to direct physics education at other groups of the student population, especially at those groups whose chief interest is not really in physics. It is to a large extent with such groups that history of science can be invaluable. The student who may not be fascinated with Galilean versus Einsteinian relativity may well be fascinated with the lives and intellectual struggles of Galileo and Einstein. (Gross, 1980, p. 19)

While it is possible to train a scientific technician without giving him or her a knowledge of the history of science, it is difficult to educate a creative scientist without such knowledge. Furthermore, some knowledge of the history of science is possibly even more important for non-science majors than for students who have already decided to devote their careers to one of the sciences. (Kauffman, 1987, p. 107)

In Western country context, many studies have indicated the problems in using the history of science in science education. For example:

Misunderstandings still hinder communication between different academic disciplines. It is disturbing to find that some prominent educators use the label "history of science" in an obsolete and misleading sense to characterize the traditional approach to science teaching, and blame it for the failings of that approach. (Brush, 1989, p. 60)
The most serious difficulty in getting any reasonable exposure of students to the history and philosophy of science in an introductory physics course is that such courses are, naturally enough, usually taught by physicists. Not only are these professors largely ignorant in matters of the history and philosophy of their discipline, but they have little tolerance of or use for these subjects, except possibly as anecdotal material suitable only for the margins of a textbook. (Cushing, 1989, p. 55)

In the Vietnamese universities nowadays, the introductory physics course for students of the General Higher Education level involves a massive quantity of information that students have to memorize within two or three semesters. They usually find physics rather difficult, irrelevant and uninteresting. Many students do not find physics helpful in promoting their scientific understanding, and they develop poor attitudes toward studying physics.

Most of the current university physics textbooks written in Vietnamese omit all historical aspects of the development of physics, the only information concerning great scientists of the past and present is limited to the year of birth and death, given in brackets after the name. Based on the ministry-controlled curriculum, the authors of these textbooks first decide what subject matter should be taught, and then figure out the best way to present the subject from a modern viewpoint, without regard for the way the subject developed historically. The history of physics is seldom drawn upon in the teaching of physics, and most physics instructors have no training in using the history of physics in their teaching.

Together with lessons draws from the history of science, physics demonstrations are rarely seen in science classrooms in Vietnam. The situation could be the result of the lack of equipment and demonstration handbooks, training for instructors, the constraints of lecture time, and the domination of “traditional” teaching methods. The textbooks deal with many concepts, but too few include guides for demonstrations or laboratory activities.
With respect to teaching methodology, most instructors in Vietnamese universities have used only traditional models in their teaching. This means that students are “passive” in the classroom and take notes from the instructor. Information is thought to be conveyed to the students directly from the instructors through verbalization and blackboards. This situation was summarized in the report *About the Educational Innovation in Higher Education* from the Ministry of Education and Training of Vietnam (1992): “The teaching methodology at most of our universities is still a passive one that relies on the convey of information directly from instructors to learners” (p. 65). The methods in which students play central roles in inquiry, cooperative learning, discovery, etc. have hardly been seen in the whole educational system. Students graduating from high-schools still keep their passive behaviors when enrolling in colleges or universities, since they know little else.

**Statement of the problem**

The purpose of this study is to determine the effectiveness of a supplementary program designed by the researcher which draws from the history of science, together with demonstrations in the teaching of the molecular-and-thermal physics section of the introductory physics course. The program aims to promote students’ understanding of the basic concepts and principles in the curriculum and to promote their positive attitudes toward physics. Within a student sample of Nhatrang University of Fisheries in Vietnam, the specific questions which this study attempted to answer are:

1. What history and lecture demonstrations could be set up and integrated into the molecular-and-thermal physics section of the basic science curriculum in Vietnam?
2. What teaching strategies could be used effectively for the case history and the lecture demonstrations in the introductory physics course?
3. Does the program help students master the concepts of heat and temperature?
4. Does the program help students develop positive attitudes toward physics?
The researcher expected that with the integration of history and demonstrations of physics into the course, together with the teaching strategies in which students can learn actively, the students could find physics more interesting and helpful to them. Accordingly, their physics understanding would also be enhanced and fostered.

**Need of the study**

Vietnam has entered an educational reform that greatly emphasizes teaching and learning quality. The university system is also looking for effective teaching strategies that could be used appropriately in Vietnamese university settings. Any exploration of teaching and learning processes such as this study is necessary and worthwhile.

One of the priorities of educational reform in Vietnam is the innovation in the teaching methodology and student evaluation. “In the first step, we should innovate our teaching methods and the ways we have used to evaluate our students. We need to increase the active participation of students based on the increasing of the resource materials” (Ministry of Education and Training, 1992, p. 21). The ways that instructors should help students learn more meaningfully are also emphasized: “The general education [at colleges and universities] needs to arm our students with a sufficiently wide range of knowledge and a habit of thinking creatively” (Ministry of Education and Training, 1992, p. 37).
Chapter 2
Review of Related Literature

This chapter is a review of selected literature associated with this study. Its major aim is to draw from ideas and research results pertaining to use of the history of science and lecture demonstrations in science teaching. The review is organized around the follow basic questions: Why, What and How should history be taught? Who needs it, and How can history of physics promote learning in science? Why should we use lecture demonstrations? How should we conduct them? Besides the ideas and analysis of science teaching, discussions on physics education will be highlighted as the subject of the study.

The history of science and science education

An historical approach to science holds promise and should be explored further as a method of increasing student understanding of the relationship among science, technology and society.

Quattropani (1978)

History and science are often thought as two different disciplines based on two different research traditions. A historian and a scientist often regard problems differently. To Klein (1972), the scientist wants “to get at the very essence of a phenomenon, stripping away all complicating features” (p. 16), while a good historian strives for “the rich complexity of fact” (p. 16) far different from the “sharply defined simple insight” (p. 17) that the scientist desires. "History is the study of events that occurred in the past while science, a cumulative discipline, embodies the discoveries of the past insofar as they are valid or relevant in the light of our present knowledge—but without reference to the conditions under which they were made" (Cohen, 1950, p. 343).

The discovery of the ratio e/m could be an example of the case. What we often see today in many textbooks, is that this ratio was discovered by J.J. Thomson, who performed an experiment in a highly evacuated tube, usually with a heated cathode; and
when a potential difference $V$ was applied between the heated cathode and anode, cathode rays of speed $v$ are produced, where:

$$V \cdot e = \frac{1}{2} m \cdot v^2$$

But actually, J.J. Thomson performed the experiment in a low vacuum condition! The historians of science were concerned with the case by looking for the answers of how J.J. Thomson experimented, what the effect actually was of using a poor vacuum, why J.J. Thomson was led to perform these experiments, how he came to his conclusions that the atom was no longer to be considered the primary, indivisible particle of matter, and what was the immediate reaction in the scientific community to these conclusions?

The introduction of historical materials into science courses is often motivated by the desire to give the future scientist not only facts and technical skills, but also the correct attitude or general methodology. The problem of how best to introduce historical materials into a physics course was first examined internationally at an International Conference on Physics in General Education held in Rio de Janeiro in 1963: "The purpose of the Seminar was not to convince anyone that history should be used in physics teaching but rather to explore and promote concrete methods for doing so" (Gee, 1972a, p. 50).

At this conference, besides the number of supporting ideas for a historical approach, there was also some doubt whether we should integrate history with science in secondary-science curricula. The American Nobel Laureate R.P. Feynman said at the conference:

"There is a difference between a science and the humanities, and an attempt to mix the two at too early an age is a danger and a destroyer of the true cultural value of science...It is impossible to teach appreciation of anything to young children; you can teach them only what the thing really is and then hope that the intelligence will produce the appreciation."

(Lewis, 1972, p. 125)

In a Unesco survey in 1966, curricula for secondary-school physics in Czechoslovakia, Federal Republic of Germany, France, USSR, United Kingdom and
USA were discussed in some detail, and in no case had the history of science been introduced in sufficient depth to be noted as a subject for study. Lewis (1972) offered three reasons which serve to explain this fact. One of these is that the discipline [history of science] is a fairly new one and hence has not had time to be fully developed as a classical method. Another is the difficulty of who is to teach it: the historian or the scientist? The third is a very real feeling on the part of some people that science is not a cultural study.

The historical approach to science teaching was used more earlier in universities and colleges throughout the world. As mentioned in the preceding chapter, a significant line of development which brought the history of science into science education began at Harvard University in the late 1940's.

Under the leadership of Conant, history of science case studies were introduced into undergraduate general education at Harvard around 1950. Conant argued that laymen need to understand the methods of science and can gain such understanding without studying at the current frontiers of research if they study how science developed in earlier times. In A Sense of History in Science, Cohen (1950) suggests:

By stressing the youth of science, and calling attention to its later conceptual evolution, we can also avoid the error of thinking that our predecessors were not quite as smart as we are. It is true that our average college senior in physics today knows more physics than Aristotle or Archimedes, and perhaps even Galileo and Newton, but he isn't more intelligent. A sense of history in science demands, then, that we attempt to find out why such intelligent thinkers in the past came to conclusions that we today consider to be such "obvious" errors, but which cannot have been so "obvious" after all. (p. 347)

The success of Conant's Harvard Case Studies in college courses, and the example of Joseph Schwab's historical text-based science course at the University of Chicago (Schwab, 1950) prompted Leo Klopfer, then at the University of Chicago, to emulate the approach in the teaching of secondary science. He and Watson produced a course of History of Science Cases for Schools [HOSC] in the late 1950's. Each of eight
cases was presented in a separate booklet containing the historical narrative, quotations from scientists' original papers, pertinent student experiments and exercises, marginal notes and questions, and space for students to write answer to questions. Teachers' guides and supplementary material were also produced. The experimental version was tested and evaluated in 108 classes with encouraging results (Klopfer & Cooley, 1963). A version of the cases was published by Wadsworth, San Francisco (Klopfer, 1969).

During the 1960's, The Project Physics Course was developed at Harvard under the leadership of Rutherford, Holton, and Watson. Significant amounts of historical material were incorporated into a complete curriculum package (text, readers, equipment, etc.). According to its directors, the three major goals of Harvard Project Physics were "to design a humanistically oriented course, to attract more students to the study of introductory physics, and to find out more about the factors that influence the learning of science" (Brush, 1989, p. 61).

After it became commercially available in 1970, the Project Physics Course was widely adopted throughout the United States. Because this project made significant use of history of science materials, its evaluation is considered as an important conclusion on the examination of how history of science might influence attitudes to science. Welch and Walberg (1972) summarized the significant effects under four headings. On "course satisfaction," one of three affective measures, Project Physics was rated significantly higher than "other physics" courses. The learning environment measure showed Project Physics classes higher in "diversity" while other physics classes were higher in "favoritism" and "difficulty." The course reaction and physics perception measures provide particularly relevant results. As a course, Project Physics received significantly higher ratings on "historical approach interesting," "math background unnecessary," and "book enjoyable to read." In contrast, other physics courses had significantly higher ratings on "most difficult course in school" and "physics must be difficult" (pp. 377-381).
Finally, "Project Physics students rated the concept Physics as more Historical, Philosophical, Social, and Humanitarian and less Mathematical and Applied than did students in other courses" (p. 382). It is important to note, in addition, that no significant differences were obtained on the cognitive measures in the course comparisons. The four cognitive measures were an achievement test, the course grade, the Test on Understanding Science, and the Science Process Inventory. The disappointed results on the Test on Understanding Science and the Science Process Inventory were explained by Russell (1981):

If *The Project Physics Course* uses historical material simply as an alternative way of teaching physics content, without emphasizing scientific processes and the understanding of science, it is not surprising that students learn the same content and, noticing that a more historical and less mathematical route can be used, perceive the subject in that light. (p. 56)

On July 1970, an International Working Seminar on the Role of the History of Physics in Physics Education was held at the Massachusetts Institute of Technology (MIT). The organizing committee took its assignment in a broad philosophical sense and decided not to pursue the question of whether the logical method is better or worse than the historical method; rather than try to persuade the unconvinced, the seminar should try to determine how history can be used in the teaching of physics, and to make known to physics teachers the kinds of resources that were available (Brush & King, 1972).

At this Seminar, when discussing the role of the history of physics in physics education in the year 2000, Dr. Charles Weiner (American Institute of Physics, New York) said:

The role that history will play in physics teaching will depend on how good the history is, how much we understand of it, and whether there exists a sound body of historical knowledge at that time. Historical knowledge must be based on detailed documentation, and it is our responsibility now, in planning textbooks and recommendations for international bodies for the decade ahead, to take some immediate action that will make possible the proper use of the history of physics in education twenty, thirty, or forty years in the future. (Brush & King, 1972, p. 47).
In subsequent years, the historical approach in science teaching continued to be one of the major topics at some international conferences: at Florida University in 1989, at Queen's University, Ontario in 1992, at University of Minnesota, Minneapolis in 1995. In the last few years there have been about three hundred scholarly papers published on the subject of history, philosophy and science teaching, and the establishment of the journal Science & Education, devoted to this subject (Matthews, 1994).

**Why history of physics should be taught**

A student should learn something about the character of scientific knowledge, how it was developed, and how it is used. He must see that knowledge has a certain dynamic quality and that it is quite likely to shift in meaning and status with time.

National Society for the Study of Education (1960)

When we look for the ways that the history of science can influence student attitudes in science, the problem is what types of influence do we seek? Some seek to improve student interest in and appreciation of science; others seek to have students understand the nature of science. "The first aim is more affective in nature; the second, more cognitive" (Russell, 1981, p. 56).

Today, students planning to become scientists or engineers constitute a small minority of the total population in any country. For example, in United States, it is somewhere between 5 and 10% of the total labor force (Klopfer, 1969). This means that more than 90% of all working people are engaged in occupations that are not directly related to science. For the nonscientist, "preparation for a scientific or science-related career cannot be the goal of education in science" (Klopfer, 1969, pp. 87-88). The education in science appropriate for *everyone* in schools and colleges is one that contributes to the individual's scientific literacy.

The development of scientific literacy must be a major purpose of science teaching... The fulfillment of this purpose can be furthered significantly
through the inclusion of history of science in the teaching of science in schools and colleges. (Klopfer, 1969, pp. 88-89).

To Klopfer (1969), one component of scientific literacy is "the understanding of key concepts and principles of science" (p. 88). By applying this understanding, the scientifically literate person is able to comprehend the phenomena and the changes in the natural world in which he or she lives and to choose courses of action that will help him or her to live in safety and in health. The more important component of scientific literacy is related to "how scientific ideas are developed" (p. 88). The scientifically literate person must learn how scientific ideas are formulated, tested, and inevitably, revised, and he or she must learn what impels scientists to engage in this activity. This understanding would help him or her to perceive consciously the newly proposed scientific concepts and ideas that flatly contradict the concepts he or she previously studied in school. Another crucial component of scientific literacy is "an understanding of the interactions between science and the general culture" (p. 88). A person who is scientifically literate would be cognizant of the multiple interactions between science and the general culture, and could utilize this awareness in his personal planning, in making political decisions, and in formulating a more comprehensive view of the world.

Matthews (1994) made a convincing case on the necessity of improving scientific literacy in general science education. He believed that the historical approach can contribute to the promotion of scientific literacy for all students; and scientifically literate persons should expect to (pp. 32-33):

1) Understand fundamental concepts, laws, principles and facts in the basic sciences.

2) Appreciate the variety of scientific methodologies, attitudes and dispositions, and appropriately utilize them.

3) Connect scientific theory to everyday life and recognize chemical, physical and biological processes in the world around them.

4) Recognize the manifold ways that science and its related technology interact with the economics, culture and politics of society.
5) Understand parts of the history of science, and the ways in which it has shaped, and in turn has been shaped by, cultural, moral and religious forces.

In discussing the educational merits of an historical approach in science secondary-school curricula, Lewis (1972) analyzed the necessity of the history of science for university and college settings (pp. 125-126):

(a) One of the characteristics of modern science, which is often difficult to present in a real and impelling fashion to secondary-school pupils, is its characteristic of rapid change. Theories and ideas which were widely held only a few years ago are now superseded and discarded, and yet physics as an exact science is taught with mathematical precision, problems are solved with accuracy and experiments are carefully evaluated for limits of error. The discipline of the history of science exposes young people to the vast chronicle of changing ideas, changing concepts, new and sometimes radical theories, to which man has had to adjust repeatedly throughout his intellectual history. The whole concept of the dynamic quality of sciences an inherent theme in the historical approach, which is often difficult, and sometimes impossible, to present in any other way than in terms of man's constant search for better explanations and truer models of the behavior of nature about him.

(b) By necessity, secondary-school education reflects a very partisan and nationalistic framework for the developing mind of the child. He must learn a particular language; the political history he is taught concentrates on his native land, geography and civil structures are clearly biased to teach him his own place in his own national home. The history of science is almost unique in presenting a body of accumulated knowledge which has been discovered by mankind as a whole irrespective of religious, national or even temporal restrictions. In presenting the development of science and the social changes which it has brought about, one can present the total story of mankind as an inseparable part of the world around him in a truly international framework. This is the type of education to which every young person in the world today should be exposed.

(c) There is a need for the future citizen to understand the modern world and its problems. Historians in the past could talk leisurely about the Bronze Age, the Iron Age, the Renaissance, the Reformation, the Industrial Revolution and so on. But today we speak of an Atomic Age, a Cybernetic Age, a Space Age, a Bioengineering Age and the significant thing is that they are all happening at once. We must understand them if civilization is not perish.

Some authors emphasize the teaching of history of science as a way to promote students' attitudes toward science. For example, Russell (1981) states:

Discussion of educational and cultural influences on attitudes toward science makes it clear that there is good reason to teach the history of
science, with careful attention to sources of misunderstanding and negative images of science. (p. 51)

By including history in our courses we can combat the prevalent dehumanized view of science which many of our students have:

A sense of history can give our students a feeling for the movement, progress, and continual change inherent in science—the idea of science not as a static body of dead facts, but rather as a dynamic, never-ending human activity with today's theories and experimental findings being merely the leading edge of a trail beginning in the past, but stretching indefinitely into the future. (Kauffman, 1987, p. 107)

What students can learn from the history is not only the success of scientists' ideas but also their mistakes. Ernst Mayr, in the opening pages of his *The Growth of Biological Thought*, commends historical study of scientists in these terms:

I feel that the study of the history of a field is the best way of acquiring an understanding of its concepts. Only by going over the hard way by which these concepts were worked out—by learning all the earlier wrong assumptions that had to be refuted one by one, in other words by learning all past mistakes—can one hope to acquire a really thorough and sound understanding. In science one learns not only by one's own mistakes but by the history of the mistakes of others. (Mayr, 1982, p. 20)

Piaget's early conjecture that young children's thinking might recapitulate earlier conceptions found in the history of science was used to promote historical approaches to teaching science. Many researchers used the history of science as a means to understand students' preconceptions in science as in Clement (1982), or help students understand some difficult concepts in science as in Lochhead & Dufresne (1989), or to help science educators anticipate students' misconceptions as in Brouwer & Singh (1983) and Wandersee (1986, 1992), or promote the students' conceptual change as in Hewson (1981) and in Sequeira & Leite (1991).

We believe that the teachers' knowledge about the history of science can promote the students' conceptual change for two different sets of reasons. The first set of reasons concerns the teachers' role and attitudes towards the teaching and learning of science and the second concerns the contribution of the history of science to a teaching strategy capable of changing students' ideas.
There is some evidence that students' conceptual development has some similarity with the development of concepts that have occurred in the history of science although it does not follow exactly the same stages. (Sequeira & Leite, 1991, p. 53)

In North America context, the need for an authentic science education has been increasing since the 1980's. In Report 36 of the Science Council of Canada (1984) the presentation of an authentic view of science is listed among the eight priorities for changing the direction of science education in Canada. "A more authentic portrayal of science would include the history of science, science, and technology and reflection on the nature of scientific knowledge" (Martin & Kass & Brouwer, 1990, p. 542). The following about coverage of the history of science and technology in American schools is from Science for all Americans (AAAS, 1989).

There are two principal reasons for including some knowledge of history among the recommendations. One reason is that generalizations about how the scientific enterprise operates would be empty without concrete examples. Consider, for example, the proposition that new ideas are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many different investigators. Without historical examples, these generalizations would be no more than slogans...A second reason is that some episodes in the history of the scientific endeavor are of surpassing significance to our cultural heritage. Such episodes certainly include Galileo's role in changing our perception of our place in the universe; Newton's demonstration that the same laws apply to motion in the heavens and on earth; Darwin's long observations of the variety and relatedness of life forms that led to his postulating a mechanism for how they came about; Lyell's identification of infectious disease with tiny organisms that could be seen only with a microscope. These stories stand among the milestones of the development of all thought in western civilization. (p. 111)

**What history of physics should be taught**

For the benefit of the many students who do not become scientists, the history of science we teach should be accurate, not distorted to suit textbook logic.

Russell (1981)

The question, "What history?" arises because the common textbook accounts of the history and methods of science are not supported by actual historical records of
characterization of methods of science is an ongoing topic of discussion among historians and philosophers of science, and their interpretations bear little resemblance to textbooks' name-and-date references emphasizing the "discovery" of particular scientific facts and laws (Russell, 1981). How to integrate history into science teaching is still under discussion. Should we use original history materials or "reconstructed" ones?

Brush (1974) focuses on the selectivity of the teacher when using historical materials:

> When the science teacher introduces historical materials he must do so in a very selective way, since his real purpose should be to teach modern theories and techniques more effectively; he can only take from the past that which seems to have significance in the present. (p. 1166)

Whitaker (1979a) notices that, in addition to an accurate historical approach, there is "another type of material which looks historical, but in which there is no attempt to convey history truthfully: the aim is solely to put over scientific facts, and the 'history' is there to provide a framework inside which the scientific facts fit easily, appear to 'make sense' and may be easily to remembered for examination purposes" (p. 108). In these materials, called "quasi-history," the history was rewritten so that it fits in step by step with the physics.

Thus quasi-history has a considerable distorting effect on the presentation of physics. Does it matter? First it must be admitted that it can amount not just to a lack of accuracy concerning history, but to a complete disregard for historical truth. It is difficult to take seriously a passionate feeling for the importance of scientific truth, coupled with a lack of interest in the truth or otherwise of historical statements. This is in itself an important objection, but our chief concern here is the effect of the complete disregard of the social aspects of science on the reader, especially if that reader is a student, anxious to learn not only the facts of science, but also about the worth of science as a human activity, and about scientists and the scientific process. The attitude of the student will determine whether he continues his studies in science, and will affect what he thinks of science in later life. (Whitaker, 1979b, p. 240)

To Whitaker (1979b), the effect of quasi-history must be to repel the student because "it presents the scientist not as a hard worker, using all the insight and experience he possesses to solve his problem, but either as a solver of trivia or as a superman,
conjuring up answers from thin air. The student will have little desire to join the ranks of the former, and little confidence to attempt to join the ranks of the latter" (p. 240).

History of physics in physics teaching doesn’t mean a biography of historical events or of great scientists. The teaching of the history of physics in a physics course should help students to know how particular problems have been attacked in the past and the ways scientists came up to solutions. Holton (1978) identifies eight components, or facets, of an historical event in science that historians and educators have to pay some attention to:

1. The scientific content of the time. What was the problem confronting the scientist? What research program helped to determine his scientific problem?

2. The historical development of the understanding of the particular problem identified. For example, in the case of Robert Millikan’s attempt to discover the basic constituents of nature goes back as far as Democritus and the Ionian philosophers.

3. The personal, intellectual struggle the scientist undergoes to identify and solve the problem. How scientists “wrestled” with the problem, how illogical elements often appear to enter into the nature of discovery.

4. The way the “private” science of the individual or group of scientists engaged in the attack on a problem interacts with the “public” science of the whole community. Private convictions of the scientist against the public demands for logical and experimental justification.

5. The psychological, or religious motives that shape scientist’s approach to a problem. Why, for example, was Millikan dedicated to the 'atomic' theory and Felix Ehrenhoft eventually committed to a continuous, non-particulate, theory of nature.

6. The sociological setting in terms of teamwork, professionalization, and institutional means for funding that influence the shape and the success of a scientific inquiry.

7. The scientific and technological interactions, the feedback loops between science and ethics, science and philosophy, science and literature.

8. The logical analysis of the research project under study, the methodology, the justification of the solution to the problem.

(quoted in Brouwer & Singh, 1983)
The historical approach in physics teaching should focus on the conceptual development of students and ways of stimulating their curiosity, inquiry and logical analysis.

In high school physics courses, students often ask precisely the fundamental questions that have puzzled the greatest scientists. Students have asked questions related to the acceleration of photons up to the speed of light, the path of an electron in an orbit around an atom, or the "cause" of gravity. Such questions have historically led to controversies among great scientists and many have led to important developments. It would build students’ self-confidence to realize that such questions are not naive or stupid but related to very fundamental ideas about our current understanding of nature. (Brouwer & Singh, 1983, p. 232)

When discussing on a basic concept, students should be encouraged to pose questions relating to its nature. For example, a teacher may begin a class discussion on gravity by asking the question, What makes bodies fall? Students are faced with a problem worth investigating, “a phenomena whose complete answer has not been found even today” (Brouwer & Singh, 1983, p. 232).

It is valuable to contrast students’ ideas with explanations that previous scientists generated. Dijksterhuis (1961), for example, lists six medieval explanations of why heavy objects fall (pp. 176-179):

1. There is an inherent tendency for a body to seek its natural place (Aristotle)
2. The medium (air) through which a body falls, drags it along (Averroes)
3. A body falls so as to be united with all other similar bodies, not necessarily to the center of the universe (Empedocles)
4. Bodies are repelled by the heavenly spheres (St. Bonaventure)
5. An attraction force is exerted by other matter in the universe (Newton)
6. A heavenly body like the earth sends out some sort of influence, which weakens the farther it goes out, and “thrusts” smaller bodies toward it (Roger Bacon)

The historical approach was also suggested in laboratory physics, with methods and materials used in original experiments. Devons and Hartmann (1970) concluded
from their experiences with the "History-of-Physics Laboratory" at Columbia and Barnard Colleges (in United States):

We can not conclude from this limited experience that our efforts and expectations have been justified, but we do have some reassurance that we are not entirely mistaken. Some students, at least, do find in this approach and emphasis an interest they do not associate with more orthodox laboratory instruction. Especially for those who have no intention of becoming professional scientists, the emphasis on historical context does seem to evoke a response that the formal science itself does not. For these students the methods of science are usually unfamiliar and alien to their intellectual concerns and aspirations. Close juxtaposition of the historical, conceptual and practical helps to connect elements so often divorced, the human and the scientific. In the history of physics laboratory the student is confronted not only with the formal contents and potentiality of science but also with a glimpse of historical actuality, the thoughts and aims, as well as the achievements, of individual persons working in a particular social and intellectual environment. (p. 49)

**How and how much history should be taught**

Teachers should make great efforts to present physics as a living discipline, rather than as a completed structure of knowledge.

Whitaker (1979b)

As indicated by Brush (1969), there are different ways of teaching physics. The *logical* approach is the one followed by textbooks where facts and theory are presented methodically. This does not mean that any other way is illogical. We nowadays interweave our coursework with *practical* laboratory work. We could also teach our physics through an *historical* approach. "However, what tends to happen is that we use a mixture of all three methods and this is probably a good thing" (Gee, 1972b, p. 54).

But how should we integrate history of physics in the curriculum? To Matthews (1994), there have been two ways in which the history of science has been included in science program: one has been the "add-on" approach, the other has been the integrated approach. In the first, the history is built as units and then added on a "standard, nonhistorical" science course. This approach has been used in a number of Australian states and the UK before the National Curriculum was implemented. In the second
approach, history is integrated into the study of science content. For instance, "mechanics will cover not just equations and practical work, but how these equations were developed and how the concepts embodied in them were formed and changed" (Matthews, 1994, p. 70). The Harvard Project Physics Course, Project 2061 in United States, and the British National Curriculum have drawn on this approach.

The *Story-line approach* to the teaching of science is recommended as an ideal way of bringing history into classroom. Arons (1988) believes the best way to attract students' attention as well as to organize a science course is by way of a story line. These stories, though shorter, are similar to the Harvard Case Histories, "that can be infused into introductory courses, without seriously affecting the amount of physics being covered" (Arons, 1988, p.14). Kieran Egan also supported this general teaching approach in his book *Teaching as Story Telling* (Egan, 1986). Similarly, Wandersee (1992) suggests using "historical vignette" in teaching science. It is "a brief (5-10-minute), carefully told, historically accurate narrative about an incident of dramatic conflict draw from the life of a famous scientist whose work is relevant to the science course being taught" (p. 429). This approach aims "to build the student’s historical knowledge base, and stimulate the student to learn more about the life of that famous scientist on the student’s own time” (p. 429).

More recently, Stinner and Williams (1993) suggest a story-line approach as a way to promote students' conceptual change. They recommended a story-line organization of a science topic, in which "the science story should be designed by the instructor, in co-operation with students, where he/she assumes the role of the research-leader and the students becomes part of an on-going research program" (p. 95).

Berger (1968) suggests two teaching approaches to integrate history into science education: (a) by telling the story of a discovery in the past, teachers can help students to understand "how an experiment can be set up, how controls can be established, how the
results can be checked" (p. 230); (b) the detective story approach, in which teachers use steps in an experiment or a discovery of the past as clues to lead students "to a solution of the mystery" (p. 230).

Lewis (1972) recommends that history could be integrated in the study of physics through case histories:

The best type of course in the history of science for a science teacher is not a series of lectures surveying several centuries, but a workshop-seminar in which each person investigates one or two case histories in considerable detail... It does not even have to be called history of science; many of the case histories could be chosen from current research for which documentation is available. The goal of the course would be to discover how science really works by examining actual discoveries. (p. 131)

Gee (1972b) suggests different kinds of materials and ideas that could be actively used for the historical approach (pp. 55-56):

- Tape-recorded scientists' voices for reconstructing a feeling of the atmosphere in the times in which a discovery was made.
- Science stories.
- Reference to the original experimental work.
- The occasional reading of a passage of an original paper or classic book during a lecture, or giving the student an off print or photocopy of an original paper.
- Designing examination questions in a manner so as to involve history.
- Historical "term" or "reading" papers. One of these could be a long essay. It could be the life and work of a famous scientist or a study of the development of a particular idea.
- Construction of time charts. These charts could be constructed showing the interrelations of science and technology, the development of instrumentation, political and scientific struggles, men of science, politics and the arts, and so on.
- Replicas. Science museums might construct replicas of various devices which may have educational value.
- Transparencies for overhead projection.
- Film loops.
Hoddeson (1974), while developing undergraduate "science and society" or "liberal arts science" courses, used authentic materials which portray scientists as people, with human concerns and motivations, in isolation, in the scientific community, and in the world at large. She enlivened her lectures with photographs of physicists at work or at leisure, with passages from their letters to colleagues describing ideas in process, or with anecdotal accounts of scientific discoveries, on tape and spoken in their own voices. Kauffman (1987) recommends that we might also use scientists' birthdays and the anniversaries of discoveries and events as a sort of a "this day in history" approach.

In United States, the American Institute of Physics' Center for History of Physics in New York is a good resource for the historical approach. It contains hundreds of hours of tape-recorded talks and interviews with scientists, providing first-person accounts of major developments in contemporary physics. It also contains unedited motion picture film, photographs, and archival documents including letters, diaries, notebooks, and unpublished autobiographies. These resources offer a wealth of behind-the-scenes information—omitted, needless to say, from standard texts—about individual personal styles, the atmosphere of scientific work, and the social processes involved in the functioning of the physics community, including its relationship to the larger society beyond it.

Studies in the role of the history of science in science teaching often come up to the question: "How much history of science is required to influence student attitudes toward a science subject?" Based on the analysis of the data from Harvard Project Physics during the 1955-1975 period and on others, Russell (1981) reached the conclusion: "If we wish to use the history of science to influence students' understanding of science, we must include significant amounts of historical material and treat that material in ways which illuminate particular characteristics of science" (p. 56).
Who needs the history

The history of physics can be used at all level of instruction for enhancing the students' understanding of physical laws and their evolution.

Brush & King (1972, p. 77)

Brush (1969, p. 272) proposes that applications of the history of science in education may conveniently be divided under three headings, though they are by no means independent of each other: (1) "General Education" (introductory high school or college courses directed primarily at general students or non-science majors); (2) "Technical Education" (pre-professional courses designed for physical science majors); (3) "Educational Education" (courses for prospective high school physics teachers).

In General Education, according to Brush (1969), students will be more interested in science if it is presented from a historical viewpoint, with the emphasis on people rather than equations. This is also a good opportunity to call attention to the role of metaphysical and even theological ideas in the earlier development of physical theories; such influences tend to be suppressed in modern science education, since scientists themselves have come to believe that they should not be important; yet it is often the philosophical issues that are most fascinating to students who may be less interested in the technical aspects of physics.

In Technical Studies, history, when introduced intelligently into a science course, can increase understanding of science and scientists, and their role in society, without detracting from the amount of scientific knowledge transmitted to the students. While the logical or traditional approach may train a scientist to solve specified problems more efficiently, the historical approach should help him decide for himself what problems are worth trying to solve.

In Educational Studies, even in preparing to teach a logical science course, with no historical content whatever, it may be useful for a teacher to learn something about the
history of science. One purpose of such a course would be to enable the teacher to counteract the misleading doctrines on "Scientific Method" which are so often presented in elementary science books, by examining in detail some examples of the ways in which scientific discoveries have actually been made.

At the International Working Seminar at MIT (in 1970), when discussing on the question “What kinds of students are we aiming at?” in terms of the historical approach, there were some significant ideas as follow (Brush & King, 1972, pp. 6-11):

Prof. Arnold Pickar (Portland State University) suggested that students of sciences other than physics should be a third category in addition to physics students and non-science majors.

Prof. R. Bruce Lindsay (Brown University) wanted to add a fourth category: prospective secondary-school or junior college physics teachers.

Prof. Samuel Devons (Columbia University): “My experience has been that bringing in the historical method is completely different for different kinds of students. For the liberal arts student it's like sugar-coating on a distasteful pill called physics which he swallows without even tasting the physics! ...Moreover, one cannot even conclude that history is successful with certain broad categories of students and not with others; one can’t say for students majoring chemistry it’s useful, but not for philosophers. In every one of these categories I’ve found students ranging over the whole spectrum with respect to their interest in history”

Prof. Giovanni Jona-Lasinio (University of Rome) commented on his experiences in teaching a course in the history of physics, attended by students in mathematics and other sciences. The students demanded a more interdisciplinary course; all of them were interested in studying the history of physics and its social meaning in the framework of the general ideology of the society in which physics developed.
The historical approach should be implemented differently "according to the age groups we are dealing with and the background philosophy behind our own national system of education" (Gee, 1972). The report from group B at this seminar included:

We reaffirm that the history of physics can be used at all levels of instruction for enhancing the students' understanding of physical laws and their evolution. To allow for individual differences among instructors, diverse approaches to introductory physics should be available, including those with historical orientation.

Although there is considerable variation among national educational systems, certain generalizations are possible. For younger secondary school students (below age fifteen) the history may be only anecdotal to accompany such laboratory-oriented courses as Nuffield (UK) and Introductory Physical Science (US). For older secondary school students (ages fifteen to seventeen) and college students (ages twenty to twenty-one) who do not plan to become scientists the history may be more biographical and expository. Thus these students could acquire a better understanding of the universe. It should be emphasized that the history of physics can show how interactions have occurred between science and society, between one scientist and another, and between scientists and nonscientists. It can show that there is no single scientific method but, instead, a number of diverse methods which reflect the personalities, needs, and times of the scientists. Using the history of physics some teachers demonstrate that man's scientific knowledge has never been complete. (Brush & King, 1972, p. 77)

What lecture demonstration is

Demonstrations take abstract principles and put them into concrete actions which are more believable and easier to comprehend.

Hilton (1981)

Demonstration has been defined and classified differently based on the ranges of meaning that scientists or educators conceive. To some people, demonstration could be "any adjunct to a lecture that it makes it more than a mere recital of words" (Taylor, 1988, p.59). According to this definition, many kinds of things could be classified in this category: hand-waving description, writing on blackboard or overhead plastic sheet, the use of slides or films, etc. At the general level, Taylor (1988) defines demonstration as
"the illustration of a point in a lecture or lesson by means of something other than conventional visual-aid apparatus" (p. 59).

Another definition given by Woodburn and Obourn (1965) emphasizes another aspects of a demonstration: "A demonstration is a planned manipulation of materials and equipment to the end that the students are able to observe all or at least some of the manifestations of one or more scientific principles operating within a phenomenon" (p. 321).

Taylor (1988, p.59) divides demonstrations into three categories:

1. Visual aids using non-conventional apparatus;
2. Analogue demonstrations;
3. Real experiments.

The unconventional visual aids in the first category could be seen as the unreal experiments in which things and equipment are used to illustrate how the real phenomena occur and work. An example for this is the use of the striped string to clarify the concept of the limit of resolution in an optical system used by Taylor (1988, p.60).

The analogue demonstration "uses a phenomenon whose behavior is sufficiently similar to that being discussed to make it valuable as in instructional aid" (Taylor, 1988, p.60).

In the third category, real experiments deal with real equipment that should be used in order to establish phenomena.

The use of the terms demonstration and experiment is often confusing. To Thurber and Collette (1964), "to be an experiment, a demonstration must be built about a problem the solution of which is unknown to the pupils" (p. 129). He also gave an example for this: The teacher who demonstrates the electrolysis of water to show that water is composed of oxygen and hydrogen is not performing an experiment. The
teacher who demonstrates electrolysis of water to find out what constitutes water is performing an experiment.

**Why demonstrations should be used**

A good demonstration can be effective in maintaining student motivation and interest in the way in which physicists deal with natural phenomena.

Eaton et al. (1960)

Advocates of lecture demonstrations have often been confronted with the similarity of their methods and laboratory classes. Why do we have to use demonstrations while the laboratory is ready at hand? Do demonstrations contribute thing any different to science education than does laboratory work? Early laboratory work was integrated in academic learning because of its ability to develop observational and inductive reasoning skills through the direct contact with the physical world.

Science educators have all agreed that the potential of the laboratory to develop the powers of the mind is an ultimate goal of science education. But often laboratory work has not "moved beyond the simple verification of scientific principles or the tedious observation of natural phenomena for purposes of mental discipline" (DeBoer, 1991, p. 108). Because of this, the laboratory work has taken the blame in part for declining enrollments in science courses in the past. Besides, the development of laboratory courses is often expensive and require space, supplies, good maintenance and a considerable portion of the time available in the teaching schedule.

Laboratory work in academic environments is supported because it provides hands-on activities needed for a full understanding of science concepts. Science educators have concluded that "the best way to learn science processes is by practicing them in the laboratory" (DeBoer, 1991, p. 230).
The weakness cited in challenging laboratory work related to its ability to develop science inquiry skills and an understanding of science. In contrast, lecture demonstrations have proved their contributions to such goals in science education.

Lecture demonstrations provide unexcelled opportunities for students to watch physicists in action, to see how they think and operate (a) when they attempt to isolate particular phenomena for study, (b) when they try to identify causes, effects, and functional relationships, (c) when, confronted by puzzling situations, they make guesses, follow hunches and construct various hypotheses, and (d) when they have to choose among alternative theoretical possibilities. (Schilling, 1960, p. 308)

Some educational researchers have tried to determine whether lecture demonstration or laboratory took the dominant role in improving student knowledge. A number of studies show that "teacher demonstrations were at least as effective as laboratory work in increasing student knowledge of science facts and principles" (DeBoer, 1991, p. 111).

To Trowbridge and Bybee (1990, p. 232), demonstrations can be justified for the following reasons:

1. **Lower cost.** Less equipment and fewer materials are needed by an instructor doing a demonstration. It is, therefore, cheaper than having an entire class conduct experiments. However, cheaper education is not necessary better education.

2. **Availability of equipment.** Certain demonstrations require equipment not available in sufficient numbers for all students to use. For example, not every student in a physics class needs to have an oscilloscope to study sound waves.

3. **Economy of time.** Often the time required to set up equipment for a laboratory exercise cannot be justified for the educational value received. A teacher can set up the demonstration and use the rest of the time for other instruction.

4. **Less hazard from dangerous materials.** A teacher may more safely handle dangerous chemicals or apparatus requiring sophisticated skills.
(5) Direction of the teaching process. In a demonstration, a teacher has a better indication of the students' thinking process and can do much to stimulate the students to be more analytical and synthetic in their reasoning.

(6) Show the use of equipment. An instructor may want to show the students how to use and prevent damage to a microscope, balance, oscilloscope, etc.

Beside the advantages that demonstrations can contribute to science teaching, they also have some limitations as Thurber and Collette (1964, p. 132) indicate:

(1) Visibility is always a problem. Students often have difficulty seeing all details of the apparatus or all details of the processes of phenomena.

(2) Students have little opportunity to become familiar with the equipment.

(3) Much scientific information cannot be grasped adequately by sight or sound alone. Odors require close-up observation. Texture is best determined by touch. Forces are more significant when muscular action is involved.

(4) A demonstration is apt to go at such a rapid pace that students do not grasp each step. Unfortunately, many students are reluctant to raise questions when they fail to follow the steps in a demonstration.

(5) During any discussion which results from a demonstration, there may be instances when certain students tend to "carry the class along", to the detriment of the others.

(6) There are few opportunities for active student participation during a demonstration. It is difficult to ensure complete mental participation while the body remains inactive.

(7) Elaborate demonstrations tend to be too convincing. The use of professionally made apparatus, in particular, adds a note of authority and makes the results difficult to question.
How lecture demonstrations should be used

The validity with which a phenomenon is revealed is the most important single criterion in establishing the value of a demonstration.

Woodburn & Obourn (1965, p. 323)

The validity of a demonstration does not rely on the modernity or the high cost of the equipment and materials included, but on the way it is conducted and its scientific implications. A lecture demonstration shouldn't stop at the simply illustrative level, but be extended enough for improving the intellectual skills of learners.

Those demonstrations are most efficient that cause students to encounter phenomena in such a way that the same intellectual processes are exercised as those that were used in the original identification and description of those phenomena. (Woodburn & Obourn, 1965, p. 323)

To Thurber and Colette (1964, p. 130) demonstrations may be used in several ways, each of which makes its own special contributions to the teaching of science.

(1) To set a problem. A demonstration may be presented without previous discussion. From the results arise problems of interest to the class.

(2) To illustrate a point. This is the most common use of demonstrations.

(3) To help solve a problem. Sometimes a problem of general interest arises spontaneously. If the answer can be discovered by an experiment that lends itself to demonstration, it may be advantageous to employ this technique.

(4) As a review. After pupils have carried out an experiment or have seen one performed, a follow-up demonstration of the same or closely related experiment makes an excellent review, usually much better than an oral review.

(5) To set a climate. An exciting demonstration is an excellent way to end a unit.

Lecture demonstrations should not always be carried out by teachers but also by students, or by both. Trowbridge and Bybee (1990, p. 232) classify the available forms for the implementation of demonstrations as follow:
(1) *Teacher demonstration.* The teacher prepares and gives the demonstrations by him or herself.

(2) *Teacher-student demonstration.* This is a team approach in which the student assists the teacher.

(3) *Student-group demonstration.* A group of students demonstrate to the class.

(4) *Individual student demonstration.* Students from an upper-level course demonstrate to students in more elementary course.

(5) *Guest demonstration.* Other science teachers or professional scientists are called in to present a demonstration.

**Summary**

The review of related literature has shown a strong tendency toward using the history of science in science education, even in introductory science courses for non-science majors. It is felt that the teaching of history of science could help science education meet its general goals and could satisfy the needs of both science and non-science learners. Matthews (1994) sums up the reasons for an emphasis on history of science (p. 50):

1) History promotes the better comprehension of scientific concepts and methods.

2) Historical approaches connect the development of individual thinking with the development of scientific ideas.

3) History of science is intrinsically worthwhile. Important episodes in the history of science and culture—the Scientific Revolution, Darwinism, the discovery of penicillin and so on—should be familiar to all students.

4) History is necessary to understand the nature of science.

5) History counteracts the scientism and dogmatism that are commonly found in science texts and classes.

6) History, by examining the life and times of individual scientists, humanizes the subject matter of science, making it less abstract and more engaging for students.
7) History allows connections to be made within topics and disciplines of science, as well as with other academic disciplines; history displays the integrative and interdependent nature of human achievements.

Much research has analyzed ways to bring history into the teaching of science at different levels, and a variety of teaching techniques have been explored for the historical approach. Besides, the efficacy of the historical approach and ways that we need to treat history in science education are still being debated as DeBoer (1991) summarizes: “Although the use of history has been proposed by some as the primary basis for the teaching of science, it has not received widespread support among science educators” (p. 230). In physics teaching there was much research on this trend on a broad range of topics and grade levels. Research on conceptual development in physics teaching is prevalent, but ways that the history of physics could promote this change is still being explored and experimented with, especially in the university context.

The use of lecture demonstrations for science teaching, especially in physics, has met with approval by many researchers and educators because of its contributions to a wide range of educational goals. One of the ideas of Pinkston (1981) could be cited as summative for a conviction of the efficacy of the integration of lecture demonstrations into introductory physics courses:

Teachers of introductory physics are above all teachers most blessed. Their subject matter is interesting, varied, vitally important, and almost always demonstrable. (p. 387)

A summary of merits and goals that history of science and demonstrations can contribute to science education could be presented as in Figure 1.
Figure 1: The contributions of history and lecture demonstrations to science education

HISTORY

Scientific humanization
S-T-S* interaction
Nature of science

LECTURE DEMO

Fun
Attitude
Scientific methods

Scientific manipulation
Mental inquiry
Observation skill

Concept development

*S Science-Technology-Society
Chapter 3
Development of the Teaching Approach

Purpose of the study

The purpose of this study is to examine the effectiveness of a suggested program in promoting positive attitudes toward physics and conceptual development for students enrolled in an introductory physics course. The program includes a case history and eight lecture demonstrations focusing on the molecular-and-thermal physics section of the introductory physics course. The program is designed to be integrated into the section within the allocated course time and it was tested with a class at Nhatrang University of Fisheries.

This chapter includes the overall design of the study, the description of the procedure, instruments and tasks used in the collection of data.

Design

The research involves the following steps:

1. The exploration of the advantages and disadvantages of the case history approach and lecture demonstrations in Vietnamese universities.

2. The development of the Test about Heat and Temperature, the Test on Attitudes Toward Physics, and the Survey of Students' Views about the Program.

3. The development of the case history approach and relevant teaching strategy.

4. The development of the lecture demonstrations and relevant learning cycle.

5. The integration of the case history approach and lecture demonstrations into the curriculum.

6. Pre-evaluation of the program.
**Subjects and treatments**

One hundred and eighty second-year university male students participated in the study. They were all enrolled in the Faculty of Mechanical Engineering of Nhatrang University of Fisheries. These students had been divided randomly into three equal-sized classes after they had successfully passed the university entrance examination.

This study was conducted during the first two months of the 1995-1996 Fall semester. In the previous semester, the three classes had been taught the mechanics, electricity and electromagnetic sections of the introductory physics course by the same instructor. During the period of this study, these classes were taught the molecular-and-thermal physics section by this instructor and the researcher. The instructor took two classes: CK 1 and CK 3 (as we will call the control classes) and the researcher took the class CK 2 (the experiment class). The three classes were taught with the same core curriculum during the same period of time (45 class periods*). The instructor and the researcher had graduated from the same university in the same year and were both working in the physics department of the university.

The instructor and researcher had agreed on the way to conduct the study and on the cooperation procedure between us for the success of the study. The instructor was continuing to teach his two control classes in the 'traditional' manner while the researcher was dealing with the experimental class using the suggested program.

The administration of two tests and a survey to the classes is described in Table 1. The Test 1 (pretest) was administered at the beginning of the section while the Test 2, the Survey and the Test 1 (posttest) were used at the end of the section. All of the tests and the survey were done anonymously.

* one class period equals 45 minutes
Table 1: The administration of the tests and survey

<table>
<thead>
<tr>
<th>Class</th>
<th>Classified</th>
<th>Test 1 (pretest)</th>
<th>Test 2</th>
<th>Survey</th>
<th>Test 1 (posttest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK 1 (60 students)</td>
<td>Control</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CK 2 (60 students)</td>
<td>Experiment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CK 3 (60 students)</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

- Test 1: Test on Attitude toward Physics
- Test 2: Test about Heat and Temperature
- Survey: Survey of Students' Views about the Program

Procedure

The exploration of the advantages and disadvantages of the case-history approach and lecture demonstrations in Vietnamese universities

- Advantages
  
  Based on the literature review, case-history approach and lecture demonstrations show potential in promoting students' conceptual development, improving their interest and motivation in the learning of physics, and helping them understand the methods, the nature and the developmental process of science. Vietnamese universities are presently concerned with innovation. Any approaches effective for the teaching and learning process that are appropriate in the Vietnamese context are being welcomed. National education policy is a priority in contemporary Vietnam, as indicated in the VII General Assembly of the Communist Party of Vietnam.

  Education and training must be considered as the prior national policy... We must modernize the curriculum and the teaching methods, democratize the
schooling and its administration. (Ministry of Education and Training, 1992, p. 14)

The integration of the history of physics into physics education was considered as a valuable approach. Dr. Nguyen Quang Lac’s paper, *Physics Teaching Methodology*, used for training Vietnamese physics teachers and instructors, says, "We should introduce adequately the history of physics in our teaching. Especially, the contradictions and the struggle during the evolution of physics should be analyzed vividly" (Nguyen, 1990, p. 21).

An exploration on the historical resources for the program in Vietnam was conducted by the researcher in August 1995. Its focus was the books on history of physics at the libraries of Nhatrang University of Fisheries and Khanh Hoa province. The result showed that there are 34 books on history of physics written in or translated into Vietnamese. Those written in foreign languages are generally unavailable. Most of these books were written for readers with basic training in the physical sciences and range from the classical to modern physics. A classification of these books by topics is indicated in Table 2.

**Table 2: Classification of books on history of physics**

<table>
<thead>
<tr>
<th>Topics</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>General development from classical to modern physics</td>
<td>8</td>
</tr>
<tr>
<td>Development on specified fields or topics of physics</td>
<td>3</td>
</tr>
<tr>
<td>Lives and contributions of famous physicists</td>
<td>14</td>
</tr>
<tr>
<td>Important historical experiments in physics</td>
<td>4</td>
</tr>
</tbody>
</table>

The above resources could support several historical approaches in physics teaching such as: case history or case analysis, as suggested by Lewis (1972), Woodburn and
Obourn (1965), story-line approach suggested by Egan (1986), Arons (1988), Stinner and Williams (1993), or workshop-seminars as recommended by the seminar held at MIT in 1970 (Brush & King, 1972).

The place of lecture demonstrations in science education has been accepted widely at the international level for decades. It has been implemented more widely with the support of advanced technology and teaching facilities. The popularity of laboratory work in academic settings has not conflicted with the use of lecture demonstrations.

Nguyen (1990), in the paper mentioned above, also underlines the role of lecture demonstration in physics teaching.

Lecture demonstration has an enormous role in stimulating and fostering students' perception. It also enhances their mental inquiry and creative thinking. Through lecture demonstration, the students are also familiar with the methods of science and logical thinking. (p. 65)

- **Disadvantages**

Although innovation in Vietnamese higher education has been implemented for years, it's still at an early phase. The role of basic science education has been emphasized, but finding support for it is still difficult. The poor economic situation and the long-time isolation from Western educational ideas have seen as significant hindrances. It also takes time for educators and administrators to understand in depth the content of the proposed innovation and to realize one's responsibility to it. In such a context, any new approaches for education should be well-planned and well-designed if they are to succeed.

The lack of relevant textbooks and reference materials is a serious problem in Vietnamese universities and colleges. Teaching facilities have also been in short supply. For instance, each university department normally has just one overhead projector. In such a situation, whole courses are often taught through lectures by using verbal or blackboard-and-chalk formats. This is a great obstacle to the introduction of any innovative approach in science teaching. However, instructors could have support for duplicating their lecture papers and distributing them to students. In this way, students could read some parts of the
curriculum on their own with the guidance of the instructors, freeing time previously taken up with lectures for new teaching strategies.

Students' familiarity with traditional teaching methods in which they are expected to take notes and learn passively is also a great obstacle for the introduction of student-centered teaching models. Students may not participate actively in classroom discussions or group learning activities at least at the first stage.

The number of books written on history of physics in Vietnamese are still small. Few contain translations of original papers by physicists which would provide a useful alternative to secondary sources. Aside from these books, other materials useful for a historical approach are difficult to find; for example, references to original experiment work, or replicas of historical experimental devices.

In Vietnam, the history of physics has only been taught as a separate course (45 class periods) for the student teachers of the physics departments at the universities of education. Student teachers are expected to improve their knowledge of the history of physics, not to bring it into the secondary curriculum as a teaching approach. Hence, those who wish to introduce historical approaches for science education have to be highly convincing about their effectiveness when dealing with educators and administrators.

Although the validity of lecture demonstrations could easily be demonstrated, support for it is still very rare. It is very difficult to find a book on physics or science demonstrations, and, the current physics textbooks do not have any place for a guide to demonstrations or do-it-yourself activities.

Equipment for lecture demonstrations is also hard to find, especially in higher education. There are few suppliers in this field—only one state company producing toys and teaching equipment designed for kindergartens, primary schools and elementary schools.
The development of the tests and the survey

- **Test on Attitudes Toward Physics**

  Although there has been a considerable amount of attitude research in science education, much of it has been criticized by science education researchers (Gogolin & Swartz, 1992). Researchers define attitudes in a variety of ways. Peterson and Carlson (1979) report in their review that there are over 30 studies a year on attitudes toward science; however, a closer look reveals much diversity in definition. Some researchers are studying scientific attitudes, whereas others are investigating attitudes toward science. According to the distinction noted by Gardner (1975), "scientific attitudes" are predominately cognitive in orientation, whereas "attitudes toward science" are predominately affective. According to the meta-analysis of Haladyna and Shaughnessy (1982), science attitudes include such different aspects as scientific attitudes, attitudes toward scientists, attitudes toward a method of teaching science, scientific interests, attitudes toward parts of the curriculum, and attitudes toward the subject of science.

  The Test on Attitudes Toward Physics in this study is a 24-item, Likert-type instrument developed by the researcher based on the general structure of the Attitudes Toward Science Inventory (ATSI) used in the study of Gogolin and Swartz (1992). Instead of comprising 6 scales with 8 items per scale as in ATSI, this test just includes 3 scales with 8 items per scale but its dimensions almost comprise the ATSI dimensions.

  The three interrelated dimensions of the test are (I) Motivation and Enjoyment in Physics, (II) Value of Physics in Career and Life, and (III) Perception of the Physics Teaching Methodology. Students were asked to respond to the force-choice system (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree). The favorable items were scored 1, 2, 3, 4, 5 and the unfavorable items were scored 5, 4, 3, 2, 1 respectively; then the items were summed across for each scale.
The test was also constructed in accordance with the purpose of this study by including some items related to the use of history of physics, lecture demonstrations and some specified teaching strategies. Therefore, future use of this test should be referred to its purpose and context.

Before implementation, the test was approved by the Head of the Physics Department and the Dean of the Faculty of Mechanical Engineering of Nhatrang University of Fisheries for administering to the whole class of second-year students of the Faculty (see Appendix A). The test used as the pretest and posttest with different item orders for examining the attitude change after instruction.

The content of the test and the identification of the favorable and unfavorable items are described in Appendix B.

- **Test About Heat and Temperature**

This 10-item test was constructed in the multiple-choice-with-free-response format. The first three choices for each item were arranged randomly into three categories: (I) Kinetic Viewpoint, (II) Caloric Viewpoint, and (III) Students' Viewpoint. The fourth choice for each item, a free response option, is used to investigate unexpected ideas of students about the item. Some of the items on the test are referred from Erickson's study (1980).

In this test, students' preconceptions are defined as the Caloric viewpoint or Students' viewpoint. The literature review results that students' preconceptions changed remarkably little after conventional instruction and their preconceptions had much common with ideas considered valid in former times. The test was used in this study to explore whether the experimental-class students' preconceptions about heat and temperature changed compared with the control-class students' after the completion of the program.

The content of the test and its answer key are given in Appendix C.
• **Survey of Students' Views about the Program**

The survey has two parts. The first is a 10-item, Likert-type instrument and the second is a free-response part. The purpose of this survey is to explore students' views on different aspects of the study, especially on its effectiveness to the students' learning process, and examine their self-evaluation of their learning.

The content of the survey is given in Appendix D.

• **Time Allotted for the Tests and the Survey**

The time allotted for the tests and the survey used in this study was distributed as follows:

- The Test on Attitudes Toward Physics: 15 minutes
- The Test About Heat and Temperature: 20 minutes
- The Survey of Students' Views about the Program: 30 minutes

**The development of the case history and relevant teaching strategy**

• **The case history**

The literature review in this study provided an overview of the ways that history of physics could be brought into physics teaching. With resources available in Vietnam now, we believe that the case-history approach could be fruitful in introductory university physics courses.

A case history could be constructed from an episode in science. "Although any episode can become a case history, the instructor will do well to choose those moments of discovery or invention for which there exists an adequately documented history" (Woodburn & Obourn, 1965, p. 309). The Conant’s *Harvard Case Histories in Experimental Science* (Conant, 1957) and Klopfer’s *History of Science Cases for School* (Klopfer, 1969) would be excellent resources for the case-history approach. In Vietnam,
several books such as Nhung Nha Vat Ly Di Tien Phong [The Pioneer Physicists] by Le Minh Triet (Le, 1980) could also be used effectively.

In comparing resources for a case history on heat and temperature, the researcher selected the Chapter 4, Is Heat a Substance? from How We Know by Goldstein and Goldstein (1978) for its intelligibility, conciseness and historical precision. The chapter talks about the rise and the decline of the caloric theory, the rise of the kinetic theory and the struggle between these two theories. This chapter was translated freely into Vietnamese by the researcher and was used as the main material for the case-history approach. The chapter was renamed Thuyet Chat Nhiet [The Caloric Theory].

My reasons for choosing a case on heat and temperature included the fact that they are often cited as popular preconceptions which are seldom changed after conventional instruction and that they both are the basic concepts of the molecular-and-thermal physics section of the introductory physics course.

The free translation of The Caloric Theory is given in Appendix E.

• The Teaching strategy

In this study, the case history was used to create the topics assigned to students for group seminar presentations. Translated copies of the case were distributed to each student of the experimental class. The class was divided into five groups of twelve students. A topic created from the case was assigned to each group. Each topic consisted of two parts: an exploration of the theory and an illustrative or verifying demonstration. The demonstrations were constructed in accordance with the historical experiments discussed in the case history.

Before the seminar presentations, each group assigned roles to its members. Some presented the theory, others performed the demonstration. The rest of the class and the instructor were the audience and asked questions to the presenters. The instructor also observed and evaluated the seminar.
The general framework for the theory presentations came from the procedure suggested by Woodburn and Obourn (1965, pp. 309-310) for case-history teaching as follows:

(1) The first phase of the framework is the selection of the episode. It should be composed of "as many as possible of the characteristics and traits of scientists at work." Its presentation starts with a review of the state of human knowledge prior to the beginning of the selected episode.

(2) The next phase is a detailed analysis of the episode. "Its purpose is to ferret out the precise events and circumstances that formed the clues leading to the new hypotheses or glimpse of a possible discovery or invention."

(3) The third phase is a close examination of "the tactics and strategy reflected in the design, conduct, interpretation, and validation of whatever experiments or investigations are included in the episode."

(4) In last phase, "the students are brought up to date on what has been learned about the topics during the years following the episode that was featured in the case history."

The focus of the teaching strategy here is the implementation of the group-work method and the seminar approach. The first is expected to bring to the class an environment in which peer collaboration is highly encouraged.

Science activities should, of course, encourage students to participate as individuals as well as in groups; but in learning scientific information, attitudes, and skills, the students should learn how to work with fellow students in seeking solutions to common problems. (Washton, 1961, p. 202)

Group work in science learning could have a great effect on the future scientist or engineer. Research in science or technology is often team research and workplaces often ask about job applicant’s team-work abilities. Students should be well prepared for future workplace practices during their learning at colleges and universities.
The student seminar is expected to let students take on the role of scientists. Students should be taught how to attack problems, read research materials and summarize them and then present them to the others. During or after the presentation, they have opportunities to learn how to argue, to defend and to express their ideas or views to others. This learning activity also makes their learning process become more active and effective as the popular adage goes, "I hear and I forget, I see and I remember, I do and I understand."

Topics for the groups' seminars are given in Appendix F.

The development of the lecture demonstrations and relevant learning cycle

- The lecture demonstrations

Within this study, the following lecture demonstrations were designed for the molecular-and-thermal physics section. They are the real experiments according to the classification of demonstrations by Taylor (1988, p. 59). These demonstrations represent an attempt to bring physics demonstrations to introductory physics courses in the Vietnamese university context, and should not be considered definitive examples. Much work and more people would need to be involved for the wide spread of this effective teaching tool in the future. When selecting or devising a demonstration, an important criterion is the availability of the equipment or materials in the Vietnamese context. The more available the equipment or materials, the more effective the demonstration would be. Each lecture demonstration is designed as a learning activity in which students can participate actively, not merely "sit back and watch."

Demonstration 1: HEAT and COLD

- Intended Learning outcomes

After participating in this demonstration, students should be able to:

- realize the relative merit of human sense on temperature.
- understand the nature of heat and cold.
- understand the Zero Law of Thermodynamics.

• **Materials**
- two identical bars of wood (labeled Bar I) and copper (labeled Bar II).
- two small identical jars of water (labeled Liquid I) and medical alcohol (labeled Liquid II).

• **Procedure**

Instructor prepares the following two tables for comparing students' temperature sensations after they touch the different substances:

<table>
<thead>
<tr>
<th>$t_1 = t_{II}$</th>
<th>$t_1 &gt; t_{II}$</th>
<th>$t_1 &lt; t_{II}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$t_1 = t_{II}$</th>
<th>$t_1 &gt; t_{II}$</th>
<th>$t_1 &lt; t_{II}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$t_1$: temperature of bar I  
$t_{II}$: temperature of bar II

Have a group of students touch two bars (one bar in each hand) and ask each of them about his/her temperature sensations, then tick it off on the appropriate place on the table. Do the same with another group of students after they have dropped the different liquids on their hands. Then, the instructor summarizes the results on each table and reveals the diversity of sensations among students.

• **Discussion questions**

- Why do we feel that some things hot and some things are cold or cool?
- Can our senses detect heat and cold accurately?
- What is the right answer among the testing results? How do you know that?
Demonstration 2: HARBOTTLE EXPLORATION

• Intended Learning outcomes

After participating in this demonstration, students should be able to:

- realize the existence of air pressure.
- understand Boyle-Mariotte Law.

• Materials

- a Harbottle (see Figure 2)
- a balloon

• Procedure

Describe the structure of the Harbottle. Put the balloon through its mouth and inflate it. With your mouth still on the balloon, cork the bottle up tight from the bottom hole. The balloon is still inflated although its mouth is open. The cork is then pulled out, and the balloon deflates immediately.

• Discussion questions

- How can the balloon be inflated in the Harbottle while its mouth is open?
- Compare the density of air in the inflated balloon and its surroundings.
Figure 2: The HarBottle with the inflated balloon
Demonstration 3: RADIOMETER EXPLORATION

- *Intended Learning outcomes*

After participating in this demonstration, students should be able to:

- realize the different heat-absorption capacities of different-colored objects.
- understand the relationship between gas temperature and its molecular translational energy.

- *Materials*

  - a radiometer (see Figure 3)
  - a flashlight

- *Procedure*

  Describe the structure of the radiometer. Adjust the light in the classroom so that the vanes of the radiometer remain stable. Turn on the flashlight and shine it on the radiometer from different distances while asking students to observe and compare the rotating speeds of the vanes under different lighting conditions.

- *Discussion questions:*

  - Why do the vanes rotate under illumination?
  - How do the vanes rotate under different illumination?
  - Do you have any suggestion for a mechanical application based on the phenomena?
Figure 3: The radiometer
Demonstration 4: SINKING DROPPER

• Intended Learning outcomes

After participating in this demonstration, students should be able to:
- compare the compressibility between air and water.
- understanding Pascal’s Law.

• Materials

- a 1.5-litter plastic clear bottle
- a dropper

• Procedure

Fill up the bottle with water. Fill the dropper with water partway and put it in the bottle so that it just floats, then cork the bottle up tight. When pressing the bottle, the dropper sinks to its bottom. Stop pressing, and the dropper floats up again (see Figure 4).

• Discussion questions

- Why does the dropper sink while pressing the bottle?
- How will the phenomena be if the water does not fill up the bottle?
Figure 4: The sinking dropper
Demonstration 5: THE MAGIC TEST TUBE

- **Intended Learning outcomes**
  After participating in this demonstration, students should be able to:
  - understand Pascal's Law
  - Explain the motion of the magic test tube

- **Materials**
  - 2 test tubes slightly different in diameter
  - a small pot (its mouth just a little bit larger than one test tube cross section)

- **Procedure**

  Fill the bigger test tube with water and then put the smaller one into it. Reverse both and we can see the smaller test tube moves upwards inside the bigger one.

  Fill the pot with water and then put the selected test tube into it through its mouth. Reverse both and we can see the test tube move upwards and then stick in to the pot while the water runs out (see Figure 5).

- **Discussion questions**
  - Why does the test tube not fall down after reversing?
  - What would happen if there were a hole at the bottom of the bigger test tube or at the bottom of the pot?
Figure 5: The magic test tube is hanging in the water pot
Demonstration 6: CAP AS FAUCET

- Intended Learning outcomes

After participating in this demonstration, students should be able to:

- understand the Basics Law of the static fluid dynamics.
- recognize the effect of surface tension of water.

- Materials

- a 1.5-litter plastic clear bottle
- adhesive tape

- Procedure

The bottle is punched with different sized holes, varying from 2mm to 10mm in diameter; then each of the holes is covered with adhesive tape. Fill the bottle with water and then cork it up tight. Remove the adhesive tape from the smaller holes and students will see that water cannot escape through these holes. Turn on the cap from the bottle, and water is ejected from these holes. The cap acts as a faucet (see Figure 6).

Now, cover the smaller holes again. Uncover the larger holes with the bottle cap still closed. This time, the water escapes slowly through these holes. If the cap is turned on, more water will be ejected from these holes.

- Discussion questions

- Why can water not escape through the smaller holes while the bottle is capped? Why it is not the same with the larger holes?
- How can the height of the water column in the bottle affect the amount of the water escaping from the holes?
Figure 6: Cap as faucet
Demonstration 7: EXPLORING SURFACE TENSION

- Intended Learning outcomes

After participating in this demonstration, students should be able to:

- experience the surface tension of liquid.
- compare the surface tension of water and oil.
- understand why oil can be used as a lubricant.

- Materials

  - a small pane of window glass (around 10 cm. x 10 cm.)
  - a shallow pan
  - a large flat surface of glass
  - a metal or wooden flat top table
  - a spring scale
  - water, oil (enough for filling the pan)
  - a string (around 60 cm.)

- Procedure

  Tape one end of the string firmly to the center of the pane. Tie a loop in the other end of the string and loop it over the hook of the spring scale and record the weight of the pane. Fill the pane with water and then place it flat on the surface of the water in the pan. Do not allow it to sink. While pulling up on the string by holding the spring scale, record the changing force exerted on the pane. Repeat the above procedure with the following changes: pour some water over the surface of the large pane of glass or table top and rest the smaller pane in this water. Record the changing force exerted on the pane while pulling up on the string as before (see Figure 7).

  Repeat the above procedure but with oil instead of water.
Figure 7: Exploring surface tension
• Discussion questions

- Explain how the surface tension can keep the pane of glass stuck to the water (or oil)

- Why does a thin layer of water (or oil) keep the pane of glass stuck better to the water (or oil)?

- Why does oil lubricate better than water?

Demonstration 8: DRINKING BIRD EXPLORATION

• Intended Learning outcomes

After participating in this demonstration, students should be able to:

- understand heat absorption during water vaporization.

- understand the relationship between temperature, pressure and volume of a gas.

- apply the Second Law of thermodynamics to explain the motion of a 'real' heat engine.

• Materials

- a drinking bird (see Figure 8)

- a glass of water

• Procedure

Describe the structure of the drinking bird and then let it work steadily.

• Discussion questions

- What is the working mechanism of the drinking bird?

- Is the drinking bird a perpetual motion machine or a heat engine? why?

- Do you have any suggestions for a mechanical application based on the phenomenon?
Figure 8: The drinking bird
• **Learning cycle**

Demonstrations are a vital part of physics instruction. They have considerable potential to keep physics fascinating for students. But their merits still depend on the ways demonstrations are brought to the students. It limits their value if demonstrations are just used to illustrate or verify something in physics. The more a demonstration can improve the students' intellectual inquiry and problem solving, the more valuable it is. Such demonstration can promote effectively students' attitudes and motivation.

The most important fruits of a lecture are not facts, they are attitudes and motivations, and a touch of dramatic emphasis via demonstrations does not go amiss. (Meiners, 1970, p. 8)

In this approach, the lecture demonstrations are expected to reach the merits and goals that are illustrated in Figure 1. In order to do this, the suggested demonstrations are designed as active learning activities with the instructor as facilitator. The overall structure of the teaching strategy devised by the researcher for such activities is described in Figure 9.

**Figure 9: Learning cycle for lecture demonstrations**
In this teaching strategy, the instructor first does the demonstration for students to observe and then guides them to recognize the relevant problems. Then, the demonstration is manipulated back and forth by the instructor or by the students to help them collect facts. In the second stage, the class is divided into small groups for finding the solutions and testing them. They should be free to run the demonstration again to check results.

In the last stage, the class meets again as a whole group, and small group representatives present their solutions. These solutions are then examined by the whole class and the instructor in order to choose the best ones. The demonstration could be done again during this phase. Lastly, the instructor guides the class to refine their best solutions and arouses students' ideas on possible applications from the demonstration.

The integration of the case history and the lecture demonstrations into the curriculum

Case-history seminars and lecture demonstrations are designed to be incorporated into the molecular-and-thermal physics section during the class time. Time and place for their integration are shown on Table 3.

The distribution of the case-history seminars and the lecture demonstrations in the curriculum are not only based on their relevance to prior knowledge but also on a necessary balance between topics. The topics that don't have relevant case-history seminars or lecture demonstrations, for instance, The First Law of Thermodynamics or Real Gas, could be incorporated with those related to previous topics.
Table 3: The integration of the case history and the demonstrations

<table>
<thead>
<tr>
<th>Lecture Topics</th>
<th>Time* (number of periods)</th>
<th>Integration Plan</th>
<th>Time (number of periods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Empirical Laws the Gases</td>
<td>3</td>
<td>Demonstration 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration 2</td>
<td></td>
</tr>
<tr>
<td>The Kinetic Theory of Gases</td>
<td>4</td>
<td>Case-history Seminar 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration 3</td>
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<tr>
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<td>5</td>
<td>Case-history Seminar 3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Case-history Seminar 4</td>
<td>1</td>
</tr>
<tr>
<td>The Physical Properties of Liquids</td>
<td>5</td>
<td>Demonstration 4</td>
<td>1</td>
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<td></td>
<td>Demonstration 5</td>
<td>1</td>
</tr>
<tr>
<td>Real Gases</td>
<td>3</td>
<td>Case-history Seminar 5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration 6</td>
<td>1</td>
</tr>
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<td></td>
<td></td>
<td>Demonstration 7</td>
<td>1</td>
</tr>
<tr>
<td>Phase Transfer</td>
<td>3</td>
<td>Demonstration 8</td>
<td>1</td>
</tr>
</tbody>
</table>

Subtotal: 27
Mid-term Exam: 2
Final Exam: 3
Total: 45 periods

* including the lecture time and time for solving exercises
Pre-evaluation of the program

The criteria against which the success of this program may be measured are (Narine, 1989, p. 120):

(i) Whether or not the purposes of the curriculum have been fulfilled.
(ii) Whether or not the resources required to implement the program are available.
(iii) Whether or not curriculum's program of study can be completed in the time available.
(iv) Whether or not the program will motivate students to study science.

• Purposes

The molecular-and-thermal physics section of the introductory physics course is introduced to the students at the General Higher Education phase in Vietnamese universities and colleges. The general goal of this period of education is to help students gain basic knowledge and understanding of a number of different sciences and familiarity with the methods of science, and to prepare them for the Specialized Higher Education phase. The case history on the caloric theory, although not covering all topics of the section, could serve as a case for improving students' understanding of the nature of heat and temperature, concepts that could not be easily comprehended through traditional teaching, enhancing students' perception on the development of science and its methods.

The seminar using historical case studies puts students in a situation to confront scientific work. Whenever students are encouraged to work for their contributions to the others, they would deal with the problem actively and therefore, benefit from it maximally.

Lecture demonstrations used with appropriate problem solving methods can promote students' understanding of basic concepts and principles and elicit intellectual inquiry. Group discussions used in the demonstration approach also help students further their social skills. The eight demonstrations suggested in the program, covering some of
the basic concepts and principles in the section, could serve as a source for attaining the
goals of the program.

- **Resources**

Although the case history selected from *How We Know* (Goldstein & Goldstein, 1978) is not currently available in Vietnam, a number of useful books on history of physics are available for selecting case histories. These case histories could be developed around the lives and contributions of well-known physicists, the evolution of physics as seen through a particular episode or a historically decisive experiment in physics.

Most of equipment for the suggested lecture demonstrations can be found in Vietnam, and most of it is homemade. The silver radiometer (for the Demonstration 3) might need to be ordered abroad (one of the possible source is EFSTONSCIENCE Inc.; Fax #: (416) 787-5140; item code #: R60529 - price: CND 13.95)

- **Time**

Time constraints pose a crucial problem for any kind of curriculum development. In Vietnamese universities, the lack of teaching facilities, textbooks and training in teaching methodology have made the science classroom the place where information is conveyed from instructors to students. Most of the course time is devoted to lecture presentations, and one of the most common ideas heard from instructors is "too much to teach and not enough time to teach it." With the program for innovation in the higher education system of Vietnam, different teaching styles have been suggested and more teaching facilities have been supplied to make the learning process more effective and meaningful. In Nhatrang University of Fisheries, lecture presentations may now take up a maximum of 60% of the course time, and instructors are encouraged to use the rest of the time for student-centered learning activities.

This program is designed to use the 40% of class time devoted to student activities. A detailed schedule can be found in Table 3.
Motivation

Physics has the reputation of being a difficult course because of the large amount of mathematics involved and the huge number of concepts, formulas, principles, constants, etc.—that must be memorized. Boredom and lack of motivation are problems for students.

The combination of case history and lecture demonstrations could provide students an interesting and intrinsically motivating physics program because of their diversity in satisfying educational objectives as shown in the literature review. The suggested teaching strategies in which students play central roles should provide motivation during the learning process.

In this study, the student motivation is also enhanced by the assessment tool. Traditionally, the final score for a course in Vietnamese universities is based on the midterm and final. This method does not give weight to a variety of learning strategies and therefore, it cannot give support for student motivation during the learning process. The suggested method for calculating the final score for each student based on his/her achievement and the quality of his/her group's activities in this program is shown in Table 4.

By this method of student evaluation, scores for seminar and lecture demonstrations are marked for the whole group. It means that all of the group members have the same mark for each of their learning activities. This way of scoring can enhance the cooperation between group members and promote their team-work skills. The score for a seminar would give weight to the quality of the cooperation between group members and the group's report. The score for a lecture demonstration would evaluate the group report submitted after group discussion on the questions given in each lecture demonstration and would be used as bonus points for final scores.
The above scoring method was discussed with students in the experimental class before being implemented. It is hoped that it was a useful tool to motivate students during their participation in the program.

**Table 4: Distribution of student score**

<table>
<thead>
<tr>
<th>Category</th>
<th>Core weight</th>
<th>Bonus weight</th>
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</thead>
<tbody>
<tr>
<td>Final exam</td>
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<td></td>
</tr>
<tr>
<td>Mid-term exam</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Seminar</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Demonstration 1</td>
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<td>2%</td>
</tr>
<tr>
<td>Demonstration 2</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 3</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 4</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 5</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 6</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 7</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>Demonstration 8</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>100%</strong></td>
<td><strong>+ 16%</strong></td>
</tr>
</tbody>
</table>
Chapter 4
The Results

This chapter deals with the summary and the analysis of the data collected throughout the field test that was conducted at Nhatrang University of Fisheries in Vietnam. The data sources include the Test on Attitudes Toward Physics, the Test About Heat and Temperature, the Survey of Students’ Views about the Program and the Discussion held at the end of the study between the researcher and members of the Physics Department of Nhatrang University of Fisheries. The administration distribution of the tests and survey is presented in Table 1.

For clarifying the effectiveness of the program, the evaluation questions and relevant instruments were identified. These questions were based on the goals of the program that were indicated in Chapter 3.

**Evaluation question 1:** How do students in the experimental and control classes compare in their attitudes toward physics?

*Instrument:* Test on Attitudes Toward Physics

**Evaluation question 2:** How do students in the experimental and control class compare in their understanding about heat and temperature?

*Instrument:* Test about Heat and Temperature

**Evaluation question 3:** What are students’ and instructors’ views about the program?

*Instrument:* Survey of Students’ Views about the Program and Discussion among instructors

The logic charts that described the ways the goals were expected to be reached by the lecture demonstrations and by the historical approach are presented in Figure 10 and Figure 11.
Figure 10: Logic chart and teaching strategy of lecture demonstrations

- Demonstration
  - Fact finding
    - Solution finding
      - Application recognizing
        - Attitude
        - Understanding

- Teacher & student demonstration
- Group discussion
- Class debate
Figure 11: Logic chart of historical approach

- History of physics
- Scientific evolution
- Nature of science
- S-T-S* interaction
- Scientific methods
- Concept development
- Attitude
- Understanding

* Science-Technology-Society
Test on Attitudes Toward Physics (TATP)

This test was administered for the experimental class CK 36-A2 as the pretest and for the experimental class and the control classes CK 36-A1 and CK 36-A3 as the posttest. The student’s presence in the class was not mandatory, therefore the number of students taking the test was not the same from pretest to posttest. Data collected were separated into three scales:

Scale 1: Motivation and Enjoyment in Physics
Scale 2: Value of Physics in Career and Life
Scale 3: Perception of the Physics Teaching Methodology

The coefficient alpha method developed by Cronbach (1951) was used to consider the reliability of the test (see Table 6). The coefficients on the pretest ranged from 0.436 to 0.526; on the posttest, the coefficients ranged from 0.036 to 0.726. Only one coefficient was above 0.70, the suggested criterion (Fink and Kosecoff, 1985).

The construct validity of the test was determined in the form of item-to-scale correlations (see Table 7) by using the experimental class data. On the pretest, 11 coefficients (46%) were above the minimum acceptance level of 0.30 (Gable, 1986) and on the posttest, 3 coefficients (12.5%) were above this minimum level. There were only two coefficients (item 10 and item 24) being above the acceptance level for both pretest and posttest.

The T-tests were conducted on each scale, between the pretest and the posttest of the experimental class. Results showed that (see Table 8) only the scores on the scale 3 (perception of the physics teaching methodology) increased significantly after instruction.

One-way Anova was used to compare the scores of the posttests of the classes on each scale (see Table 9, Table 10 and Table 11). It revealed a significant increase in scores of the experimental class against the control classes on scale 3. The rather low correlation
between scales (see Table 12) couldn’t support to a multivariate comparison between classes for further investigation.

Because of the random division of the students in the three classes and the same instructor and instruction they had had in the previous semester, there was an assumption that the three classes had no difference on their attitudes toward physics at the beginning of the study. Therefore, results from the data analysis could be interpreted to support the idea that the program was favorably viewed by the students—they enjoyed the approach, and felt their learning of physics had been enhanced as a result.
Table 5: Range of scores on the TATP

<table>
<thead>
<tr>
<th>Scale</th>
<th>CK 36-A2 Pretest (N = 51)</th>
<th>CK 36-A2 Posttest (N = 49)</th>
<th>CK 36-A1 Posttest (N = 49)</th>
<th>CK 36-A3 Posttest (N = 43)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Range</td>
<td>Low</td>
</tr>
<tr>
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<td>21</td>
<td>37</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>39</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>35</td>
<td>18</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 6: Alpha Coefficients for the three scales of TATP

<table>
<thead>
<tr>
<th>Scale</th>
<th>CK 36-A2 Pretest</th>
<th>CK 36-A2 Posttest</th>
<th>CK 36-A1 Posttest</th>
<th>CK 36-A3 Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.501</td>
<td>0.386</td>
<td>0.418</td>
<td>0.726</td>
</tr>
<tr>
<td>2</td>
<td>0.526</td>
<td>0.406</td>
<td>0.346</td>
<td>0.600</td>
</tr>
<tr>
<td>3</td>
<td>0.436</td>
<td>0.314</td>
<td>0.036</td>
<td>0.049</td>
</tr>
</tbody>
</table>
Table 7: Item-to-scale correlation for the TATP (from experimental class data)

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale 1</th>
<th>Item</th>
<th>Scale 2</th>
<th>Item</th>
<th>Scale 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
</tr>
<tr>
<td>1</td>
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<td>0.381</td>
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<tr>
<td>2</td>
<td>0.237</td>
<td>0.099</td>
<td>0.319</td>
<td>0.401</td>
<td>0.464</td>
</tr>
<tr>
<td>3</td>
<td>0.214</td>
<td>0.272</td>
<td>0.360</td>
<td>0.273</td>
<td>0.329</td>
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<tr>
<td>4</td>
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<td>0.239</td>
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<td>5</td>
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Table 8: Scores on TATP of the experimental class CK 36-A2

<table>
<thead>
<tr>
<th>Scale</th>
<th>Pretest (N = 51)</th>
<th>Posttest (N = 49)</th>
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<th>Probability</th>
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<td>Mean</td>
<td>SD</td>
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<tr>
<td>1</td>
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<td>2</td>
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<td>3</td>
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<td>31.35</td>
<td>2.95</td>
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</table>

(*not significant)

Table 9: Comparison of TATP (posttest) on the first scale of the classes CK 36-A2, CK 36-A1, CK 36-A3

<table>
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<tr>
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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
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<td>31.5</td>
<td>15.8</td>
<td>1.47</td>
<td>0.234</td>
</tr>
<tr>
<td>ERROR</td>
<td>138</td>
<td>1481.5</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>140</td>
<td>1513.0</td>
<td></td>
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</tr>
</tbody>
</table>

INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

<table>
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<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
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<tbody>
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<td>32.469</td>
<td>2.686</td>
<td>(---)</td>
</tr>
<tr>
<td>CK 36-A1</td>
<td>49</td>
<td>31.367</td>
<td>3.154</td>
<td>(---)</td>
</tr>
<tr>
<td>CK 36-A3</td>
<td>43</td>
<td>32.163</td>
<td>3.958</td>
<td>(---)</td>
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</table>

POOLED STDEV = 3.276

Table 10: Comparison of TATP (posttest) on the second scale of the classes CK 36-A2, CK 36-A1, CK 36-A3

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<th>MS</th>
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<th>p</th>
</tr>
</thead>
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<td>FACTOR</td>
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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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<th>MEAN</th>
<th>STDEV</th>
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</thead>
<tbody>
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<tr>
<td>CK 36-A1</td>
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<td>32.367</td>
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<td>31.977</td>
<td>3.713</td>
<td>(---)</td>
</tr>
</tbody>
</table>

POOLED STDEV = 3.138
Table 11: Comparison of TATP (posttest) on the third scale of the classes CK 36-A2, CK 36-A1, CK 36-A3

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
<td>2</td>
<td>430.69</td>
<td>215.34</td>
<td>27.51</td>
<td>0.000</td>
</tr>
<tr>
<td>ERROR</td>
<td>138</td>
<td>1080.14</td>
<td>7.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>140</td>
<td>1510.82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
<th>POOLED STDEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK 36-A2</td>
<td>49</td>
<td>31.347</td>
<td>2.955</td>
<td>2.798</td>
</tr>
<tr>
<td>CK 36-A1</td>
<td>49</td>
<td>27.490</td>
<td>2.670</td>
<td></td>
</tr>
<tr>
<td>CK 36-A3</td>
<td>43</td>
<td>27.930</td>
<td>2.755</td>
<td></td>
</tr>
</tbody>
</table>

--- +----f +----f +----f +----f +----f
--- +----f +----f +----f +----f +----f

27.0 28.5 30.0 31.5
Table 12: Correlation matrix between scales of TAT-P

<table>
<thead>
<tr>
<th></th>
<th>Scale 1</th>
<th>Scale 2</th>
<th>Scale 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK 36-A2 Pretest</td>
<td>0.070</td>
<td>0.174</td>
<td>0.326</td>
</tr>
<tr>
<td>CK 36-A3 Posttest</td>
<td>0.559</td>
<td>0.294</td>
<td>0.404</td>
</tr>
<tr>
<td>Scale 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale 1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test about Heat and Temperature (TAHT)

This test was administered to the experimental class CK 36-A2 and the control class CK 36-A1 at the end of the study. After the administration, the test was summed across ten items for each viewpoint choice for each student. Therefore, the maximum value for each choice category or for the whole for each student is ten. The students’ explanation for each item was analyzed and then classified into one of the three viewpoints. Actually, most of these explanations were categorized as students’ viewpoint. Because of the random division of the students in the three classes, there was an assumption that these classes had no difference in knowledge of physics inherited from high school physics.

The proportions of students who answered items correctly for the test were presented on Table 13. The correlation coefficient between the proportions of the two classes is 0.867 ($\alpha_{cm} = 0.632$, $p = .05$). This result is supportive for the internal consistency of the test.

The data analysis (see Table 14) revealed that the means of the viewpoint choices on the Kinetic category for both experimental class and control class were almost the same (5.59 and 5.52). With almost equal choices on the Caloric Viewpoint and Students’ Viewpoint, the experimental class showed a significant smaller number on the choices of the Caloric Viewpoint compared with the control class; but the number of choices on the Students’ Viewpoint was higher respectively.

This result could be interpreted that the treatment did help the students to discard the caloric viewpoint when explaining thermal phenomena, but not necessarily improve thinking about the kinetic viewpoint. Accordingly, these students showed higher preference on using their own explanation or schema whenever possible.
Table 13: Proportions of students who answered items correctly for the TAHT

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK 36-A1</td>
<td>79%</td>
<td>70%</td>
<td>68%</td>
<td>48%</td>
<td>82%</td>
<td>14%</td>
<td>48%</td>
<td>36%</td>
<td>43%</td>
<td>54%</td>
</tr>
<tr>
<td>CK 36-A2</td>
<td>93%</td>
<td>50%</td>
<td>62%</td>
<td>43%</td>
<td>83%</td>
<td>26%</td>
<td>62%</td>
<td>36%</td>
<td>50%</td>
<td>55%</td>
</tr>
</tbody>
</table>

Table 14: Comparison of viewpoint choices between the experimental class CK 36-A2 and the control class CK 36-A1

<table>
<thead>
<tr>
<th>Choices</th>
<th>CK 36-A1 (N = 44)</th>
<th>CK 36-A2 (N = 42)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Kinetic Viewpoint</td>
<td>5.52</td>
<td>1.759</td>
<td>5.59</td>
<td>2.073</td>
</tr>
<tr>
<td>Caloric Viewpoint</td>
<td>2.27</td>
<td>1.370</td>
<td>1.78</td>
<td>1.335</td>
</tr>
<tr>
<td>Students' Viewpoint</td>
<td>2.21</td>
<td>1.250</td>
<td>2.63</td>
<td>1.650</td>
</tr>
</tbody>
</table>

(*not significant)
Survey of Students' Views about the Program

The survey was only administered to the experimental class, with 51 students participating in it. Data from the survey could help the researcher understand students' views on different aspects of the study, learn how they reacted to the suggested teaching strategies, get feedback and their self evaluation on their learning. The data could also be used to examine the reliability of the other tests administered in this study and analyzed above.

Likert-type items

The analysis of these data does not emphasize the total scores of the items but the response pattern of each item. Scores of some items (score of an item equals to the number selected on scale) were compared with the related items or scale of the Test of Attitudes toward Physics (posttest) and the Test about Heat and Temperature for validating their matches and re-examining their reliability.

Scores of the Likert-type items are presented in Table 15. Histograms and response patterns on the items are displayed in Figure 12 to Figure 21. Generally, the data showed fairly high scores on all items except item 10 ($\bar{x} = 3.36$). These means the students' views on different aspects of the program were highly positive.

Item 1 ($\bar{x} = 4.06$) and item 4 ($\bar{x} = 4.75$) of the survey were in accordance with the item 1 ($\bar{x} = 4.12$) of the TATP on the enjoyment dimension, or with the Motivation and Enjoyment in Physics scale of the TATP ($\bar{x} = 32.47/8 = 4.06$).

The high positive scores of item 6 ($\bar{x} = 4.26$) on group-discussion were in accordance with the scores of item 24 ($\bar{x} = 4.16$) of the TATP on the same issue. A similar result was obtained between item 7 ($\bar{x} = 4.12$) of the survey and item 22 ($\bar{x} = 4.31$) of the TATP on the use of the seminar model.
The mean score of item 9 ($\bar{x} = 4.46$) was higher than the mean score of the scale Perception of the Physics Teaching Methodology ($\bar{x} = 3.92$) of the TATP.

High scores of item 3 ($\bar{x} = 4.06$) and item 5 ($\bar{x} = 4.26$) on the cognitive self-evaluation were not supported by the data from the TAHT. However, the score of item 10 ($\bar{x} = 3.36$) on students' self-evaluation was in accordance with the unchanged result of the TAHT from the experimental class.

Free-response essay

In the second part of the survey, the students of the experimental class were asked to write about their own ideas and recommendations on the instructors' teaching methods and on the course. There were 45 students having ideas, and their writing was then codified into categories by the researcher as presented in Table 16. These categories were explored in an effort to examine the students' views that might not be revealed through the administration of the tests and survey mentioned above. Verbatim accounts of the essays were used in the data analysis, both in Vietnamese and in English translation.
### Table 15: Scores on the Survey of Students’ Views about the Program

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.06</td>
<td>4.00</td>
<td>0.76</td>
</tr>
<tr>
<td>2</td>
<td>3.90</td>
<td>4.00</td>
<td>0.83</td>
</tr>
<tr>
<td>3</td>
<td>4.06</td>
<td>4.00</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>4.75</td>
<td>5.00</td>
<td>0.56</td>
</tr>
<tr>
<td>5</td>
<td>4.26</td>
<td>4.00</td>
<td>0.77</td>
</tr>
<tr>
<td>6</td>
<td>4.26</td>
<td>5.00</td>
<td>0.91</td>
</tr>
<tr>
<td>7</td>
<td>4.12</td>
<td>4.00</td>
<td>0.82</td>
</tr>
<tr>
<td>8</td>
<td>4.16</td>
<td>4.00</td>
<td>0.93</td>
</tr>
<tr>
<td>9</td>
<td>4.46</td>
<td>5.00</td>
<td>0.70</td>
</tr>
<tr>
<td>10</td>
<td>3.36</td>
<td>3.00</td>
<td>0.63</td>
</tr>
</tbody>
</table>

### Table 16: Distribution of students’ ideas on the teaching methodology and on the course

<table>
<thead>
<tr>
<th>Related Topics</th>
<th>Numbers of Ideas</th>
<th>Percentage (N = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of physics</td>
<td>4</td>
<td>8.9%</td>
</tr>
<tr>
<td>Student seminar</td>
<td>6</td>
<td>13.3%</td>
</tr>
<tr>
<td>Lecture demonstrations</td>
<td>24</td>
<td>53.3%</td>
</tr>
<tr>
<td>Group discussion</td>
<td>3</td>
<td>6.7%</td>
</tr>
<tr>
<td>Student evaluation</td>
<td>5</td>
<td>11%</td>
</tr>
<tr>
<td>Program extension</td>
<td>4</td>
<td>8.9%</td>
</tr>
<tr>
<td>Phase-transfer examination</td>
<td>4</td>
<td>8.9%</td>
</tr>
<tr>
<td>Problem-solving emphasis</td>
<td>4</td>
<td>8.9%</td>
</tr>
<tr>
<td>General supported ideas</td>
<td>16</td>
<td>35.5%</td>
</tr>
</tbody>
</table>
• History of physics:

There were four students having ideas on the integration of the history of physics into the curriculum. They didn’t have any recommendations for better ways in dealing with the history of physics, but they all agreed on the necessity of having an understanding of it.

One student indicated clearly what he got from the historical approach:

About the instructor’s teaching methods, I think that they are suitable with the cognitive capacity of most of us. To me, the course does help me to understand the origin and the evolution of science in general, and of the physics in particular. It also helps me to know about the nature of the caloric theory and makes me more interested and fascinated in physics.

• Student seminar:

Among the six ideas on the student seminar, half of them supported it because of its relevance to higher education. As one of the students writes:

In my opinion, the instructor’s teaching methods are really suitable to the learning style of undergraduate students, especially with the student seminar and group discussion learning.

Another half of the ideas focused on the limitations of this learning style or gave recommendations:
- students had to spend too much time for reading materials and preparing for the seminars,

- class discussion should be held instead of student seminar,

- there were not enough relevant resources for investigating deeply and broadly the case history.

- Lecture demonstrations:

This was the topic that gained the largest number of students’ ideas. All of the twenty four ideas supported highly this approach because of a variety of benefits:

- developing physics understanding was the most popular idea. The students expressed the view that the demonstrations helped them, not only understand clearly the concepts and principles related with the course, but also gave them abilities to explain lots of related phenomena.

The methods that the instructor uses in this thermal physics section are very fascinated and hardly seen before. There were a lots of phenomena that I couldn’t explain until learning in this class. Such methods help me to gain a basic understanding on thermal physics.

- improving interests and motivation in learning physics was also a popular sentiment among the ideas. The integration of the demonstrations was reported to eliminate the “tediousness” that the students often faced within theory courses, and made them participate actively in the class. One of the students commented that the previous teaching methods that he had encountered were “the same” until this course, and the methods used in the program made him really interested.
developing mental inquiry and critical thinking were the main thoughts of four students. Demonstrations and group discussions allowed them to become more “active” and “brain-storming” during the course. They felt so “happy” to “discover the principles” explaining phenomena occurring around them. They found that some demonstrations were “very simple” but their physics implications were so “surprising.”

There were nine students who recommended having more demonstrations for the physics course. They found them valuable in understanding the physical world and stimulating their learning.

In my opinion, lecture demonstrations are very necessary. They should be used as many as well because they develop our interests in physics and help us understand the applications of physics.

Two other students were interested in ways to include demonstrations in lectures. The first student thought that the demonstrations should be conducted some time after, but not immediately following, the related theory in the lecture. By doing this, students could review the theory and apply it to explain the phenomena. On the contrary, the second student suggested that the lectures should follow the demonstrations since they could make the lectures “more understandable.”

- Group discussion:

Group discussion was held as a part of the learning cycle suggested for the lecture demonstrations. This activity was expected to create an environment for sharing ideas between students and working toward common goals. Three students reported that the discussions were very exciting although they experienced some difficulty in sharing their own ideas with their peers. They all agreed that the demonstrations were a good source for stimulating ideas among group members and keeping discussions lively. One student
confessed that he had never participated in such a style of learning, but he believed that it would be very useful for university students. Another student gave the following general comment:

The instructor's teaching methods are very valuable in the way to incorporate together the lectures, the demonstrations, the group discussions and the seminars. I think these methods should be implemented to another courses.

- Student evaluation:

There were five students having ideas on the way to evaluate students in the course. As presented in Table 4, the final mark of each student was not only based on his final and mid-term exam but also on the success of his group presentations in the seminars and on the quality of his group’s reports in demonstrations. Another special aspect of the evaluation was the bonus weight counted for demonstration reports. Three of the five students supported this method of evaluation because of its capacity to balance student’s achievement on different facets of his learning and to encourage him to work with his group. It was also reflected as a good motive for students to develop their critical thinking and skill of inquiry. One student commented that it was not fair to give the same score to all group members when their contributions were different. He recommended that student self-report should be considered for grading instead the group’s report.

- Program extension:

Four students expressed their appreciation of the program because of its advantages in promoting students’ logical thinking. As one wrote:

These teaching methods help students to think logically and more deeply.
Students also indicated that such teaching methods, especially lecture demonstrations, should be used in other classes or courses.

In my opinion, the instructor's teaching methods are so good. I wish the same methods would be used for the next classes or courses and more demonstrations would be available.

Such statements might be interpreted as evidence of the effectiveness and the necessity of the program, especially lecture demonstrations, in the Vietnamese university context. Students don't like heavily theoretical lectures and they really want their learning be more and more dynamic.

- Phase-transfer examination:

As mentioned before, university education system in Vietnam is organized in two phases: the General Higher Education Phase and the Specialized Higher Education Phase. The first phase includes three semesters of course work. Generally, students who finish the first phase have to pass an exam, the phase-transfer exam, before entering the second phase.

The students involved in this study had four months before writing the phase-transfer exam. This exam required knowledge of three major courses (physics excluded), and therefore much preparation of the students. Four students commented that they didn’t have enough time at home for the physics course because of the above exam, although they all supported to the program. They suggested that the program should be implemented for first-year students, who don’t have to face the phase-transfer exam.
• Problem-solving emphasis:

With traditional teaching methods, time allocated for solving physics problems is about 15 to 20 percent of the course time. In this program, only 10 percent of the time was allocated to solving problems because of the time allocated to the suggested activities. During the time for solving problems, the researcher gave students directions for comprehensive problems and details of solutions for advanced problems. While the number of problems decreased, several “thinking questions” related with each course topic were assigned to the students.

Four students required more time for solving problems because they thought they hadn’t learned sufficient problem-solving skills for the final physics exam. Being familiar with the traditional teaching method, students often expect too much from the instructor in preparing them for the solutions to assigned problems. Any change in teaching methods somehow has to face the learning styles that were built formerly in each student.

• General supported ideas:

Sixteen students expressed their support for the program in general ways, not specified in any topics. They all agreed on the effectiveness and the necessity of the program for university learning. Most of them wrote that they “really like” what had been done in the class. One student evaluated the teaching as follows:

To my understanding, the instructor’s teaching methods are the most valuable and understandable ones.

Beside these supportive ideas, students had some recommendations for the program:
- it should have some physics seminars reported by instructors to help students broaden their knowledge of physics and its applications,

- students should be supported in their learning with more relevant resources,

- the program should be focussed more on technical applications of physics, since the students were all major in mechanical engineering.
Figure 12: Histogram and response pattern of the item 1 of the Survey

Did you feel interested while working with the caloric theory?

Not interested 1 2 3 4 5 Very interested
0% 2% 19.6% 49% 29.4%

Figure 13: Histogram and response pattern of the item 2 of the Survey

Did the study of the caloric theory help you to understand more about the evolution of science?

Not helpful 1 2 3 4 5 Very helpful
0% 2% 33.3% 37.2% 27.4%
Figure 14: Histogram and response pattern of the item 3 of the Survey

N = 51

<table>
<thead>
<tr>
<th>scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
</tr>
</tbody>
</table>

Did the study of the caloric theory help you to understand more clearly the nature of heat and temperature?

Not helpful | 1 | 2 | 3 | 4 | 5 | Very helpful
             | 0% | 2% | 23.5% | 41.2% | 33.3%

Figure 15: Histogram and response pattern of the item 4 of the Survey

N = 51

<table>
<thead>
<tr>
<th>scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Did the lecture demonstrations help you to be more interested in physics?

Not helpful | 1 | 2 | 3 | 4 | 5 | Very helpful
             | 0% | 2% | 0% | 19.6% | 78.4%
Figure 16: Histogram and response pattern of the item 5 of the Survey

Did the lecture demonstrations help you to understand the related physics principles more clearly?

Not helpful  1  2  3  4  5  Very helpful
0%  2%  13.7%  41.2%  43.1%

Figure 17: Histogram and response pattern of the item 6 of the Survey

Do you think that the group-discussion model used in the class is necessary?

Not necessary  1  2  3  4  5  Very necessary
0%  3.9%  19.6%  23.5%  53%
Figure 18: Histogram and response pattern of the item 7 of the Survey

N = 51

<table>
<thead>
<tr>
<th>Scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>

Do you think that the student seminar model used in the class is necessary?

Not necessary 1 2 3 4 5 Very necessary

0% 3.9% 15.7% 45.1% 35.3%

Figure 19: Histogram and response pattern of the item 8 of the Survey

N = 51

<table>
<thead>
<tr>
<th>Scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
</tr>
</tbody>
</table>

Do you agree with the evaluation methods used in the class?

Strongly disagree 1 2 3 4 5 Strongly agree

2% 2% 17.6% 35.3% 43.1%
Figure 20: Histogram and response pattern of the item 9 of the Survey

N = 51

<table>
<thead>
<tr>
<th>scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>27</td>
</tr>
</tbody>
</table>

Do you think that the teaching approach used in the class is effective for the course?

Not effective | 1 | 2 | 3 | 4 | 5 | Very effective
0% 3.9% 0% 43.1% 53%

Figure 21: Histogram and response pattern of the item 10 of the Survey

N = 51

<table>
<thead>
<tr>
<th>scale</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

How do you evaluate your understanding of the course?

Really bad | 1 | 2 | 3 | 4 | 5 | Very good
0% 7.8% 49% 43.2% 0%
Discussion of the Physics Department

This study received strong support from the Physics Department of Nhatrang University of Fisheries during its implementation. The Department was also interested in investigating how effective the program was and to what extent the study results could be useful to other physics classes. At the beginning of the study, the research design and content were discussed with the members of the Department; and during the study the researcher had weekly informal talks with them about its on-going progress. At the end of the study, a two-hour meeting was held among the seven members of the Department to evaluate the study. At this meeting, the researcher presented a report included the process of the study and its preliminary results (including the finals scores of the students, results from the Survey of Students’ Views about the Program), followed by a general discussion of the study. An instructor of the Department kept notes of the discussion. The discussion notes were codified by the researcher and summarized into two categories: case-history seminar, and lecture demonstration with group discussion.

Case-history seminar

All of the members agreed that the history of physics should be introduced to students because it could promote their understanding of physics concepts and principles, help them to be familiar with the methods of science and develop their positive attitudes toward physics. They also agreed unanimously that student seminars were most appropriate to make the history of physics well-explored and effective. Such an approach also developed in students several necessary skills in developing expertise in science or technology. One commented that case histories are often too “theory-emphasized” so that they might be too difficult to be interesting to non-science major students. In such cases, he suggested, the history seminars should exploit the lives and contributions or anecdotes of
famous physicists. Another member noticed that the major material used as the case history in the study, *Thuyet Chat Nhiet* [The Caloric Theory], was not an easy-to-understand paper which included lots of detailed research anecdotes. In addition, references for this topic were not available to most of the students.

One member suggested that we could use the student seminar model to deal with different aspects of physics, for example, the applications of physics in technology. He said that he had used to work with his classes in this way and that its effectiveness had been "remarkable." He argued that non-science major students are often more interested in applied science.

**Lecture demonstration with group discussion**

The members of the Physics Department were highly interested in the demonstrations and the relevant learning cycle used in the study. They all agreed on the significant role of demonstrations in promoting students' understanding in physics, in developing their critical thinking and attitudes toward physics. They unanimously supported the researcher's idea that demonstrations should include as many "ready-to-make" apparatus as possible in the Vietnamese context. The eight demonstrations suggested in the study were judged to be "relevant" and "effective" by the Department members. One member suggested that the university should have funds for purchasing "modern demonstrations" that keep up with the developing technology, and that a "demonstration room" for the Department be built.

The learning cycle suggested for the demonstrations was debated among the department members. Four of them supported it, while the other three said there is not enough time in the course to implement such a learning cycle for each demonstration. To them, we should choose few demonstrations to use in conjunction with the learning cycle, and operate the rest simply to illustrate some points in the curriculum. The members all
agreed on the necessity and the benefits of group-discussion activities for university students, but most of their concerns related to the practicality of this approach, given the lack of classrooms and in large class sizes.

The most meaningful result of the discussion was the decision by the Department to integrate the history of physics and lecture demonstrations into the introductory physics course at the university. The Department agreed on planning a long-term study to explore different possibilities in teaching the history of physics and to build up more lecture demonstrations for the introductory physics course.

The meeting of the Department generated the following conclusion, cited in a report submitted to the University Board:

The student seminar on history of physics is a valuable subordinate activity. It could develop students’ interests and understanding on the ideas of physics and its evolution. Besides, students could be familiar with the methods of physics research. The Department considers it as an necessary activity for the introductory physics course at our university.

The use of demonstrations in teaching physics is very beneficial. It also develops students’ interests and critical thinking. The Department acknowledges its importance in teaching physics and the necessity to build up a set of lecture demonstrations for the physics course at our university.

Head of the Physics Department
Chapter 5
Discussion and Recommendations

This chapter deals with the summary of the results obtained from the data analysis in Chapter Four and identifies the major limitations of the study. Some recommendations are then outlined for further studies.

Summary of findings and limitations

On the attitudes toward physics

Results from the Test on Attitudes toward Physics (TATP) revealed that the program did increase the students’ awareness of and positive attitudes toward the physics teaching methodology that was utilized. This result was strongly supported by the data from the Survey of Students’ Views about the Program. This finding could be explained by the implementation of the new teaching strategies in which the students were placed at the center of their learning process. Seminars in case history and group discussions and class debates in demonstrations did help the students to discover themselves and to be motivated in their learning. “Invitations to inquiry” inherent in the lecture demonstrations really forced them to open their minds and make them think critically. Therefore, the impact of the utilized teaching strategies on students’ perception about university teaching methodology was more positive than the traditional methods that the students had experienced in which they had merely sit back and taken notes from instructors.

The TATP didn’t find any significant difference between pretest and posttest scores on the first two scales: Motivation and Enjoyment in Physics, and Value of Physics in Career and Life. This disappointing result might be explained by the following possible reasons:
i- The mean scores of the classes on these scales in pretest and posttests were around 31 and 32 (maximum score on each scale is 40). These rather high scores could be evidence that the students might become alerted to the kinds of behaviors that were expected or favored. Therefore, they might tend to choose high positive levels on the scales in order to please the instructor.

ii- Some items on these scales (e.g., items 2, 3, 6, 8, 10, 11, 12) were probably not well-constructed or sufficient enough to reveal any significant difference after treatment or between different treatments. Some behaviors related to attitude might require more time and suitable treatment in order to be changed (e.g., the sense of value of physics in career and life).

On the understanding of heat and temperature

Data from the Test about Heat and Temperature (TAHT) did not show an improved understanding of the concepts of heat and temperature. In the Survey of Students' Views about the Program, when asked: “Did the study of the caloric theory help you to understand more clearly the nature of heat and temperature?”, there were 74.5% of the experimental class choosing the levels helpful and very helpful on the item scale. The free response of the survey also indicated students' expressions on the effect of the program on students' understanding. Of course, these kinds of data were not enough to answer how or how much the students' understanding on heat and temperature was developed.

To this point, we may raise the crucial questions as follow:

i- Did the treatment not emphasize adequately on the kinetic theory while working with the caloric theory?

For the control class, the kinetic theory was included in a separated chapter with four class periods, and was sometimes recalled in the next chapters. In the case history
"The Caloric Theory," used for the experimental class, the kinetic theory just began to develop during this episode and didn't dominate in the struggle with the caloric theory. This aspect may be the explanation for the result analyzed above in which the understanding of the kinetic molecular theory of the experimental class not to be improved better than the control class.

ii- Was the treatment not enough to improve students' understanding on heat and temperature?

In this program, the case history seminars were allocated with class 5 periods (one class period for each seminar). The lecture demonstrations dealing with the kinetic molecular theory are numbers 1, 2 and 3. Perhaps, some more demonstrations related clearly with the kinetic molecular theory should be included, or the kinetic molecular theory should be emphasized more during groups' discussions or class debates.

The result of the TAHT somehow repeated the disappointing result of the Harvard Project Physics Course on the cognitive measures that was analyzed in the literature review (pp. 11-12). And once again, the recommendation of Russell (1981) cited on page 24 about the amount of historical material to be included and the ways to treat it should be considered.

iii- Were the teaching strategies not well-planned enough to make change in students' understanding?

In the implementation of the case history approach under the form of student seminar, each group of the experimental class dealt with a sub-episode of the whole period, from the rise to the declining of the caloric theory. Each group was expected to investigate at a basic level this whole period in order to gain an adequate background of the theory. It is likely that students focused on their group work and, therefore, did not gain enough understanding about the case. The unequal roles of group members in the presentations
were probably also a problem: the members not assigned to class report work may have spent little time in exploring the case.

This program was designed to maximize students’ participation during the activities through group discussions and class debates. Because of the large number of students in the class, some students did not have opportunities to observe and manipulate the demonstrations themselves, and therefore these students may not experience enough of the demonstrations to stimulate their further participation in making sense of the phenomena.

iv- Was TAHT not a good instrument to measure students’ understanding about heat and temperature?

Although TAHT was designed to explore different students’ viewpoints on heat and temperature, it may contain some disadvantages that limited its effectiveness:

- It may not easy for students to apply what they understand in certain contexts to explain similar phenomena in different contexts. Practical explanations often require a thorough understanding on the situation and experience.

- The time constraint of the test administration (20 minutes) may have caused “hurried responses” on the items and, therefore, its may not accurately reflect students’ understanding of the problems and the concepts of heat and temperature.

On the teaching strategies

The teaching strategies used in the program involved guiding student discussions of the case history, and guiding them through the learning cycle during the lecture demonstrations. The data supporting the effectiveness of these teaching strategies could be gathered from the TATP, the Survey of Students’ Views about the Program and the discussion of the Physics Department of Nhatrang University of Fisheries.
As mentioned above, data from the TATP revealed a statistically significant increase on Perception of Physics Teaching Methodology of the experimental class after the program. This result implied that the teaching strategies were favorably viewed and useful to the students and, therefore, suitable within the context of the university. Data from the survey also supported this conclusion regarding the use of lecture demonstrations. In the free response of the survey, there were few ideas (13.3%) related to the use of history seminar, and these ideas were slightly divergent on its merits.

The teaching strategies were basically accepted by the members of the Physics Department. Their recommendations focused on the use of student seminars in different areas of physics (especially in applied physics) and the necessary balance of time allocated to lectures and learning activities.

On the case history and the demonstrations

The program included a case history and eight lecture demonstrations that were integrated into the molecular and thermal physics curriculum. The case history on the caloric theory did help the students gain knowledge in the evolution of science although there were ideas that students couldn’t find enough relevant references on the topic and it took time to read through. The demonstrations, except the radiometer (in Demonstration 3), could be built by instructors themselves or purchased in Vietnam at low expense. Data from the TATP and the survey showed that the demonstrations more effective in illustrating or verifying a number of crucial points in the curriculum, and in eliciting students’ inquiry in physics. They were also perceived by the students as being “fun and interesting.”

Much of the discussion of the Physics Department focused on the demonstrations. Members agreed on the beneficial impact of demonstrations on physics learning, and their availability in the context of the university.
The major disadvantage of these lecture demonstrations is that they are difficult to conduct effectively in large classes. Five of the demonstrations (Demonstration 1, 4, 5, 6 and 7) could easily be duplicated for use in small groups. This is an area for further development and research.

**Recommendations**

This study was conducted in a technical university, its participants being second-year students enrolled in the Faculty of Mechanical Engineering. Because the subjects were technical majors, the study results might be specialized to them. An implementation and research of the program for science-major students would be warranted because of their higher interests in pure science. Students majoring in social studies could also benefit from the program because of the social-science interaction involved in the history of physics and the demonstrations.

Science curricula in Vietnamese universities are expected to change. Time for introductory physics courses may even decrease. The number of students in basic science classes in many Vietnamese universities is increasing. Large classes are difficult to organize for group learning, which was emphasized in the present program. In such cases, historical materials should be used as home readings, and demonstrations should be used mostly for illustration and verification purposes.

The case-history approach could be effectively used for exploration about the lives and contributions of famous physicists, the resources for which are available in Vietnam. Some other episodes in physics are also available for case histories. Other approaches for integrating history, story-line (Arons, 1988; Stinner and Williams, 1993) for instance, could be useful for introductory physics courses. Further studies on historical approach in teaching science in the Vietnamese context could develop on a variety of merits of the
approach that were explored in the literature review, especially on improving students' understanding of the methods of science and the interaction between science, technology and society through history. Resources for the historical approach is a topic also worthy of further consideration.

Student seminars should be held for university physics courses as a way to improve students' knowledge and research skills. Topics for the seminars could range from theoretical ones to physics applications in technology. Group learning is also beneficial to university students. How students can benefit from group learning should be a prominent issue for study since Vietnamese students are generally not familiar with this active style of learning.

The strong support for the use of lecture demonstrations from the students and the instructors gives evidence for the need to develop them not only in the molecular-and-thermal physics section, but also in other areas of the introductory physics course. The use of these demonstrations should emphasize ways to encourage inquiry. The learning cycle suggested in this study needs further studies to explore its effectiveness.

The rather low alpha coefficients of the TATP suggest a thorough revision would be required for further studies. The context for administering the test and the time allotted should also be considered. Other instruments for exploring students' attitudes (e.g., interview and observation) should be investigated. The TAHT and the Survey of Students' Views about the Program proved to be more reliable. Finally, the investigation into students' understandings of heat and temperature requires further research. Students' preconceptions or misconceptions on these concepts and others, and the teaching strategies that could improve them or changed them, need to be explored widely.
List of References


Appendices

Appendix A

Socialist Republic of Vietnam
Independence, Freedom, Happiness

Ministry of Education and Training
Nhatrang University of Fisheries

ACKNOWLEDGMENT LETTER

August 21, 1995

Simon Fraser University
Burnaby, BC V5A 1S6
Canada

According to the proposed research of Mr. Le van Hao, we allow Mr. Hao to teach a pilot course on Molecular and Thermal Physics for the class CK 36-2 during the period August 21, 1995 to October 13, 1995 (involves 45 periods). Mr. Hao is also permitted to administer the Test on Attitudes Toward Physics to the second-year students at the Faculty of Mechanical Engineering.

Dr. Quach Dinh Lien
Vice Rector
Dean of the Faculty of Mechanical Engineering
Appendix B

TEST ON ATTITUDES TOWARD PHYSICS

SD: Strongly Disagree; D: Disagree; U: Undecided
A: Agree; SA: Strongly Agree

**Motivation and enjoyment in physics**

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**Value of physics in career and life.**

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The favourable items: 1, 2, 4, 6, 8, 9, 11, 13, 15, 17, 18, 20, 22, 24
Appendix C

TEST ABOUT HEAT AND TEMPERATURE

Circle the best explanation for each of the following items. If you circle the choice d ("none of the above is correct"), please give your own explanation at the space underneath the relevant item.

1/ An object A has a higher temperature than an object B means:
   a. A has more heat than B.
   b. particles in A move faster than particles in B.
   c. A is easier heated than B.
   d. none of the above is correct.

Your explanation:
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2/ An object A has more thermal energy than an object B means:
   a. the temperature of A is higher than the temperature of B.
   b. A has more heat than B.
   c. A has more particle kinetic energy than B.
   d. none of the above is correct.

Your explanation:
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3/ A hot object A is cooled down when it contacts a cold object B shows:
   a. A has more thermal energy than B.
   b. the temperature of A is higher than the temperature of B.
   c. A has more heat than B.
d. none of the above is correct.

Your explanation:
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4/ When an object A contacts an object B in an isolated system and A has more thermal energy than B, then:
   a. Heat in A will decrease, heat in B will increase.
   b. A will be cooled down, B will be heated up.
   c. nothing changes if they had the same temperature.
   d. none of the above is correct.

Your explanation:
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5/ When we heat one end of a metal rod with a flame, the whole rod will get hot because:
   a. the agitated motion of the particles at the heated end spreads to other particles all the way through the rod.
   b. a heat fluid from the flame goes into the rod and moves along it.
   c. the high temperature of the flame spreads to the whole rod.
   d. none of the above is correct.

Your explanation:
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6/ A vacuum flask can keep coffee hot because:
   a. the kinetic energy of the coffee particles decreases very slowly when bumping into few particles in vacuum.
   b. heat cannot flow away from the coffee when the flask is closed.
c. heat particles from the coffee can go through the vacuum but very slowly because just few particles in vacuum attract them.

d. none of the above is correct.

Your explanation:

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7/ When we continuously beat a iron rod with a hammer on an anvil, the rod becomes hot because:

a. the rod has being deformed during beating.

b. an amount of heat flows from the hammer and the anvil to the rod.

c. the iron particles have been agitated.

d. none of the above is correct.

Your explanation:

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8/ The temperature of water in a cup decreases when an ice cube is added because:

a. there was a heat fluid flow from the water to the ice cube.

b. the water particles lose some of their speed by bumping into the ice particles.

c. the coldness of the ice cube spreads to the water.

d. none of the above is correct.

Your explanation:

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9/ If we heat a closed flask containing an amount of gas, the temperature of the gas will increase because:
a. the gas particles will move faster.
b. the gas will attract a heat fluid from the heat source.
c. the gas particles will expanded.
d. none of the above is correct.

Your explanation:

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10/ If we heat two cubes of equal size of iron and wax at a same temperature, we would expect that the wax will melt sooner because:

a. wax is softer than iron.
b. the wax particles will move faster than the iron particles under heating.
c. wax attracts heat particles more better than iron.
d. none of the above is correct.

Your explanation:

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Answer key:

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Appendix D

SURVEY OF STUDENTS' VIEWS ABOUT THE PROGRAM

Let us know your views about some aspects of the course by circling the appropriate number following each item.

1/ Did you feel interested while working with the caloric theory?

Not interested 1 2 3 4 5 Very interested

2/ Did the study of the caloric theory help you to understand more about the evolution of science?

Not helpful 1 2 3 4 5 Very helpful

3/ Did the study of the caloric theory help you to understand more clearly the nature of heat and temperature?

Not helpful 1 2 3 4 5 Very helpful

4/ Did the lecture demonstrations help you to be more interested in physics?

Not helpful 1 2 3 4 5 Very helpful

5/ Did the lecture demonstrations help you to understand the related physics principles more clearly?

Not helpful 1 2 3 4 5 Very helpful

6/ Do you think that the group-discussion model used in the class is necessary?

Not necessary 1 2 3 4 5 Very necessary

7/ Do you think that the student seminar model used in the class is necessary?

Not necessary 1 2 3 4 5 Very necessary

8/ Do you agree with the evaluation methods used in the class?

Strongly disagree 1 2 3 4 5 Strongly agree

9/ Do you think that the teaching approach used in the class is effective for the course?

Not effective 1 2 3 4 5 Very effective
10/ How do you evaluate your understanding of the course?

Really bad 1 2 3 4 5 Very good

Finally, we wish to have your own ideas or recommendations on the instructor’s teaching methodology and on the course in the space below.

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Appendix E

THUYET CHAT NHIEU

[THE CALORIC THEORY]
THUYẾT CHẤT NHỊET

1. Nhiệt là gì?


2. Thuyết Chất Nhiệt (Caloric Theory)
Vào cuối thế kỷ 18, nhà hoa học Phap Lavoisier đã xây dựng những nền mỏng cần bốn cho môn hoa học. Ông là người đầu tiên tạo ra sự chú ý cho nhiệt như một sự phải hóa. Gas oxygen trong không khí với những chất khác. Ông cũng đã đưa ra một danh sách các nguyên tố hoá học chẳng hạn như: oxygen, hydrogen, nitrogen, sulfur, carbon, sát... Trong danh sách này, ông đã liệt kê “nguyên tố” calorigique là chất có tự thua và nhiệt. Quan điểm cho rằng những chất như chất không phải là mới, mà có thể có nó như một chất biến khác của quan điểm cho rằng lửa cũng là một “nguyên tố”. Điều khác hồn ở đây là, trong bộ cảnh lý thuyết về cầu đến nguyên tử của vật chất đằng hình thân, nhiệt cũng được xem như một chất có cấu tạo từ những hạt. Vì nhiệt nhìn thấy như chất không bị biến đổi, mỗi hạt nhiệt là một chất cũng đong đếm y là không ta thấy hạt. Nhiệt nguyên tử rất nhỏ, hạt đong đếm những hạt chiếu, hay còn gọi là đong đếm nhiệt.

Do bởi nhiệt di chuyển khả thể do hồn những chất khác nên ngã ta đã cho rằng những hạt nhiệt phải rất nhẹ và hình dạng. Quan điểm này đã được dùng để giải thích không sao nhiệt có thể truyền đi để đong đếm mà còn được lý giải lại ở sao nhiệt không nào hau hoặc nhiệt không xảy ra. Do cả chất đong đếm bởi tất năng nên người ta cũng cho rằng các hạt nhiệt hoặc đong đếm chịu sự hấp dẫn bởi các người tạo hình những trong các chất. Sức liên kết của các hạt nhiệt cũng được giải thích là do các hạt nhiệt. Sau khi hấp dẫn bởi các người tạo các chất. Đạo xung quanh các nguyên tử này và việc làm cho không quan gì của các nguyên tử lớn ra: hoặc là về các hạt nhiệt từ đây lẫn nhau. Giải thuyết từ đây này cũng được dự đoán để giải thích tại sao nhiệt truyền đi đong đếm và các vật nóng để bị người di.
3. Thể Dục Đồng Nắng

Càng từ rất xa xưa, con người đã nhận ra rằng sự cơ sở, hoặc ma sat, giữa hai vật cùng làm phát sinh ra nhiệt. Tù do đã phát sinh ra quan niệm rằng nhiệt không phải là một chất, mà là sự rung động của vật được xem như hoàn toàn. Sự rung động này có tần số rất cao nên thái chung ta không nghe được, và chỉ được cảm nhận khi chúng ta sử dụng vật đó. Cũng có quan niệm khác cho rằng nhiệt phát xuất từ sự chuyển động của các nguyên tử tạo thành vật, và chuyển động của nguyên tử này, dần dần đến chuyển động của nguyên tử khác do sự va chạm trong quá trình chuyển động.

4. Nguyên Gốc Của Thể Dục Chất Nhiệt

Chúng ta biết rằng khi cho một vật nóng tiếp xúc với một vật lạnh thì vật nóng sẽ người, còn vật lạnh sẽ người lạnh hơn. Hiện tượng này làm cho ta có một suy nghĩ trục quan và tư liệu là phải có một cái gì đó được truyền từ vật này sang vật kia.

Chúng ta hãy hình dung có hai thời sát, mỗi thời có gán một nhiệt kế và nhiệt độ của chúng là 100°C và 0°C. Khi hai thời sát được tiếp xúc xung nhau, nhiệt độ của một nhiệt kế tăng lên, nhiệt độ của nhiệt kế khác lại giảm. Điều gì đã xảy ra giữa hai vật? Phải chăng đã có cái gì đó chuyển từ vật nóng sang vật lạnh, hoặc chuyển từ vật lạnh sang vật nóng, hoặc chuyển theo cơ hai chiều? Biếu hiện của hai nhiệt kế, từ chỗ chỉ hai nhiệt độ khác nhau đến khi cho hai giọt dầu, cùng không thể cung cấp thêm một thông tin nào khác. Nhưng kinh nghiệm khác nhau trong cung sống, ví dụ như khi dùng nước, khi bỏ đôi bàn tay trên lửa, đã làm cho người ta đã gặp nhận ra rằng phải có chất gì đó chuyển từ vật nóng sang vật lạnh.

Theo kĩ lưỡng, các di doan vật chất có sự bùng nổ trong các ngăn cách giữa các bàn như nhiệt, điện, quang và tật cả chúng đều được xác nhận những "chất" khác nhau. Do đó những "chất" này đã chuyển và làm cho nhiều chất bính thường một cách dễ dàng (như chất hóa chất, chất lượng truyền qua thụ tinh, dien truyền qua thanh kim loại), nhưng chúng đều không mà những "dòng chảy tính tế" (subtle fluid). Cung trong khoảng trống Gian nay, lý thuyết về các tạo nguyên tử của vật chất đang được phát triển nhiều và khoa học tìm ra những dòng chảy này cũng được cấu tạo từ các nguyên tử, nhưng là những loại nguyên tử rất nhẹ. Tuy nhiên, nhiều nhà khoa học khác không chấp nhận hình ảnh cấu tạo nguyên tử của các dòng chảy đặc biệt này.

5. Sử Bạo Toán của Nhiệt

Có một hệ quan trọng phát xuất từ quan điểm cơ học là một chất cụ thể, và hệ quả này là một trong những luận điểm cơ bản của thuyết Chất Nhiệt.


Do nhiệt là một chất, nên nó cũng phải được bạo toán. Lượng nhiệt trong và từ rất lớn. Nếu ta muốn tiếp ứng nhiệt tài một nơi nào đó: ví dụ như để đun một bình nước, thì nhiệt độ một nơi khác cần được làm bằng với tổng lượng nhiệt phải không đổi. Quan niệm về sự bạo toán của nhiệt như trên tuy không đúng nhưng nó cũng đã góp phần kiến thức duoc nhiều hiện tượng về nhiệt.
6. Joseph Black

7. Nhiệt và Nhiệt Động
Một trong những đóng góp chính của Black là xay dung các khái niệm về nhiệt và nhiệt độ. Như cãu cãnh phân chia nhiệt giữa hai khái niệm này có thể thay đổi qua thí nghiệm sau: đặt nóng một cái đĩa sợi bằng nhau khoảng hai gram và một thời gian khó phân biệt với khối cùc nhiệt độ cao nào đó (kiểm tra bằng nhiệt kế). Sau đó thay cái đĩa và thời gian vào hai chậu nước như nhau và dùng tích và nhiệt độ. Ta sẽ thấy cái đĩa bị làm người ngay mà hầu như không làm tăng nhiệt độ của chậu nước: cón thời sat thì có thể làm cho chậu nước chứa nóng sói lên.
Thí nghiệm trên cho thấy cãu míf phái có hai khái niệm tách biệt: một khi nhiệt độ đã biến điện cường độ của nhiệt (tục nhiệt độ), một khi nhiệt độ đã chỉ tổng lượng nhiệt mà một vật có được (tâ đang gọi tất là nhiệt). Sự phân biệt này cũng tủa như khi ta so sánh hai khối khi: một trong ruột xe đạp, một trong ruột xe đập. Hai khối khi này có thể cùc cùng một giải trí áp suất nhưng khi đó luồng khí ch-command trong ruột xe đạp phát lên hơn nhiều làm luồng khí ch城市管理 trong ruột xe đạp.

8. Nhiệt Động Củi Cung và Hạng Bịp
Một trong những vấn đề mà Black nghiên cứu là xác định nhiệt độ cửi cùng khi cho nhiều chất có nhiệt độ khác nhau tiếp xúc với nhau. Thúc nghiệm cho thấy: nếu hòa 1 kg nước ở 100°C và 1 kg nước ở 0°C ta sẽ được 2 kg nước ở 50°C. Kết quả này phù hợp với trực giác bình thường của chúng ta. Nhưng điều gì sẽ xảy ra nếu ta bỏ 1 kg sả: ở 100°C vào trong 1 kg nước ở 0°C Nhiệt độ cùng có phải là 50°C không? Câu trả lời cho trực giác này là không!
Nhưng thử nghiệm đầu tiên đã được làm với mức và thủy ngân. Kết quả cho thấy: nếu trơn hai luồng nước và thủy ngân có cùng khối lượng với nhau thì nhiệt độ cùng của chúng lại rất gần với nhiệt độ bản đầu của nước. Cư thế: một khối lượng nước ở 0°C trơn cùng một lượng thủy ngân tương đương ở 100°C sẽ có nhiệt độ sau cùng là 50°C. Nhiều nhà khoa học đã lập tài thí nghiệm trên với hai luồng nước và thủy ngân không phải có cùng khối lượng mà là cùng thể tích. Nhưng kết quả vẫn không khác trên dạng kế. Black cho rằng lượng nhiệt cần thiết để tăng nhiệt độ của một vật lên một độ không phải chỉ phụ thuộc vào số lượng của chất đó, mà còn phụ thuộc vào những đặc tính khác của vật. Từ đó ông ta đã đưa ra khái niệm nhiệt dung riêng của một chất (specific heat) . Dúc định nghĩa là lượng nhiệt cần thiết để làm tăng nhiệt độ của một đơn vị khối lượng của một chất lên một độ.

9. Nhiệt Luồng và Nhiệt Dung
Trong lao luân của Black, quan niệm về sự bắt toan của nhiệt dòng về trớ cần bàn. Theo quan niệm này thì trong một hệ có lập, khi một vật nóng được tiếp xúc với một vật lạnh, lượng nhiệt热量 ra từ vật nóng sẽ chảy hết vào trong vật lạnh chứ không thể có phần nào biến mất được. Trố lại với thí nghiệm trên đây, lượng nhiệt热量 ra từ thủy ngân khi nhiệt độ của nó giảm từ 100°C xuống 30°C phải bằng với lượng nhiệt mà nước đã nhận
duc de tang nhiet do tu 0°C len 30°C. Luc ngiet (hoac nhiet luong) noi tren phai tuyen voi do thay doi cua nhiet so cho nen tu co phuong trinh:

\[ V = C x (t_2 - t_1) \]

trong do t1 va t2 la nhiet do dau tien va nhiet do cuoi cung cua vat. Q la nhiet luong ma vat vao hoac thay ra. C la mot hang so co gia tri chu xam trong nhiet luong.

De co the xac dinh C cho cac chat khac nhau, phai co mot chat duoc chon lam chuan. Nguoi da duoc chon lam nhiet vu ne: vo 1 kg nuoc, neu cho t1 - t2 = 1. C(nuoc) = 1 cal. (Cal) - 1 Cal = 10^3 cal

Dat q = la nhiet luong do thu ngan that ca. qa la nhiet luong do nuoc thu vao. Do \( q = \frac{V}{q_a} \) nen ta co:
\[ C_t \times (100^\circ C - 30^\circ C) = C_n \times (30^\circ C - 0^\circ C) \]
hoac:
\[ C_t \times 97 = C_n \times 3 \]
vay:
\[ C_t = \frac{3}{97} \times C_n = \frac{3}{97} \times 1 = 0.03 \]

Nhiet dung rieng cua cac chat khac co the duoc xac dinh theo phuong phap tren gia tri nhiet dung rieng cua mot so chat khac nhau co the xem trong phan phu lục

10. Nhiệt Đông: Thuyết Chất Nhiệt hay Thuyết Đông Nắng?
Bằng cách xác định như trên, các nhà khoa học nhận thấy rằng những chất tạo bởi các nguyên tử nặng (ví dụ thủy ngân, sắt, đồng...) thì có nhiệt dụng riêng nhỏ hơn các chất tạo bởi các nguyên tử nhẹ (ví dụ nước).
Black đã lập luận rằng thuyết Đông Nắng không thể giải thích tính chất này, bởi vì nếu xem nhiệt độ chuyển động của các nguyên tử thì đối với nguyên tử càng nặng nó càng phải cần nhiều năng lượng để đạt được một mức độ chuyển động nào đó. Điều này phải có nhiệt dụng riêng càng lớn. Mac đã thuyết Chất Nhiệt cũng không thể đưa ra sử giải thích thỏa đáng cho trường hợp này, nhưng ít nhất Lý Luân của nó không dẫn tới kết quả mà thường như do vì thuyết Đông Nắng. Phát môt số năm sau thì, khi mà thuyết Đông Nắng đã phát triển hoàn chỉnh, tất cả các vấn đề đã được giải quyết.

11. Nhiệt Ẩn và Thuyết Chất Nhiệt
Theo thuyết Chất Nhiệt, nhiệt là một chất có thể chảy liêun tự tự một vat nong sang một vật lạnh cho đến khi sự can bằng nhiệt giữa hai vật xảy ra. Như vậy, rõ ràng là để cho nhiệt độ của một vật có thể tăng nhanh có cần phải duoc cung cấp nhiệt. Nhưng liệu nhiệt độ của một vật có thể tăng khi nhiệt độ của một vật không tăng không? Câu này có vẻ ngon ngàng, nhưng ta hãy xem xét sự tương ứng của hai phần biểu sau:

1/ Đảm tắm nhiệt độ, cần phải thêm nhiệt.
2/ Nếu nhiệt độ duoc thêm vao, nhiệt độ phải tăng.
Black đã khám phá ra rằng phát biểu như không đúng, phát biểu tự hai không phải luôn luôn đúng.
Hiền tượng trạng thái của nước đã được Black nghiên cứu trước hết. Trực do nguoi ta tin tưởng rằng khi nước đã được cung cấp nhiệt, nhiệt độ của nó sẽ tăng dần. Khi đã đạt đến 100°C, nước đã lập tức tan chảy ngay va nhiệt độ của nước tiếp tục tăng khi nhiệt độ được thêm vào nước trên Hình 1. Nhưng trong thực tế, nước đã can nhiệt độ giảm để giữ nhiệt độ của nó vẫn luôn giữ ở gia tri 0°C va chỉ tăng lên sau khi khối nước đã bị hoàn toàn tan thành nước như trên Hình 1.

![Hình 1](attachment:Image1.jpg)
Không chỉ n הזכ đạ mà bất kỳ chất nào cung đều thể hiện tính chất trên trong quá trình tan chảy. Người ta đã dara ra bể nhiệt nhất ổn (latent heat), với nghĩa là lượng nhiệt cần thiết để làm cho một đơn vị khối lượng chất cần tan chảy hoàn toàn đủ độ áp suất nhất định.
(gia trí nhiệt ổn của một số chất khác nhau có thể xem trong phần phụ lục)
Trong khi thuyết Đông Nước thời bấy giờ chưa thể giải thích được hiện tượng nhiệt ổn, thuyết Chất Nhiệt đã lý giải hiện tượng này như sau: khi n adhere đã (hoặc các chất rắn khác) bắt đầu quá trình tan chảy, xuất hiện một loài phân ứng hoá học giữa các phần tử nudes đã với các nguyên tử của chất nhiệt trong đó mới một phần tử nudes đã kết hợp với một số hạt dinh các nguyên tử của hạt nhiệt để tạo thành một phần tử mới. Các nguyên tử của hạt nhiệt nạm bao quanh phần tử mới này và làm gia tăng độ linh động của nó. Sự hình thành các phần tử mới làm tiêu hao lượng nhiệt bổ sung và vì vậy nhiệt độ của hỗn hợp nudes + nudes đã không thể tăng lên được.

12. Count Rumford Xét Lai Thuyết Chất Nhiệt
   Rumford đã quan tâm đến những lý thuyết về nhiệt ngày từ thời 17 ki ngh叉 ông được đọc một công trình về lũa do nhà hòa học nổi tiếng người Hà Lan Boerhave viết trong đó nhiệt được cài là sự rung động của vật bị nhiệt động -một rung động cơ tận sở rất cao không thể nhận biết được bằng tính giác, nhưng xúc giác có thể cảm nhận được. Rumford đã làm những thí nghiệm để kiểm tra lý thuyết này nhưng không có kết quả, và về sau ông ngã theo quan điểm có nhiệt là chuyển động dòng hồn lơn của các nguyên tử tạo thành các chất.
   Rumford đã làm nhiều thí nghiệm để chứng minh quan niệm sai lầm của thuyết Caloric trong đó có ba thí nghiệm chủ chốt sau:
   1/ thí nghiệm đo nhiệt độ của nhiệt.
   2/ thí nghiệm đo nhiệt độ mà sá.
   3/ thí nghiệm về chuyển động không ngừng của nguyên tử và phần tử.

13. Thí Nhiệm Do Khối Lường của Nhiệt
   Theo thuyết Chất Nhiệt, nhiệt là một chất có thể cho nên nó phải có khối lượng cho đủ rất nhỏ. Nếu thử nghiệm cho thấy nhiệt có khối lượng thì phải chấp nhận nó là một dạng chất. Tuy nhiên, nếu thí nghiệm không chứng minh được điều này, thì cũng không thể phủ nhận được thuyết Chất Nhiệt bởi những lí lý sau. Thứ nhất, biết kỹ dung cụ đo chất nên cũng có giới hạn cua nó về độ chính xác. Khí một cái cần cho biết khối lượng của một vật bằng không, ta
chi có thể kết luận rằng khối lượng của vật đó nhỏ hơn do chính xác cho phép cả căn đáng xung đột. Điều này cũng như như khi ta sử dụng một cái căn thiết để cảm thông mùi. Thư hai, khi xem xét như là một cách không phải ai cũng cho rằng nó phải có khối lượng. Thứ ba, một số đang chất đắc biết, chẳng hạn như, án sáng có thể cảm được bằng những công cụ mà Rumford đã sử dụng. Tất nhiên Rumford đã tiến hành thí nghiệm này theo cách hệ thống càng thâm, khoa học và đã sử dụng những thiết bị càng xác nhận thiết bị này. Việc ấy là ta có thể biết được khối lượng của phần nhiệt chưa trong một bãng cách căn vật ở tai hai nhà tri nhiệt độ khác nhau. Như thế, trong thực tế thì, nghiên cứu như thế làm thấm thấu đến tính chính xác của kết quả chằng hạn như:

- Nghiên cứu của một dạng căn làm cho cảnh tay đơn của cái căn (bạn chưa biết nó) ảnh hưởng đến cơ thể bạn. Dấu hiệu vật nóng như năng lượng hệ thống.

- Một số kiến tai, chẳng hạn như: cần tạo sự bi oxi hóa rất nhanh khi ở nhiệt độ cao dẫn đến kim loại trú nên tạng trong do hút oxygen vào bắt mắt của nó.

- Nghiên cứu của một dạng căn làm không khí ở lưu lạc ở dạng lê nhiệt độ căn.

- Nghiên cứu của một dạng căn làm cho lợp không khí ở bám trên vật bay hoặc, dẫn đến vật bi nổ hoặc.

Trong thí nghiệm của Rumford, đã tránh những hạn chế trên, ông đã không căn vật nóng mà ta thấy vào đó là cảm khối lượng của một số dâu ở hai trạng thái: trạng thái nóng lúc đầu ở 0°C và trạng thái lạnh (đóng đá) cũng ở 0°C. Giữa hai trạng thái này, các căn dâu đã thái ra một lượng nhiệt độ khác nhau (hiển tượng nhiệt dàn).

Trong thí nghiệm trên, Rumford đã sử dụng loại căn cảm bằng: một bên căn đắt một số dâu, bên kia đắt một số dâu hợp của nước và rụng (khoảng đóng dâc ở 0°C) và tất cả được đặt trong một bình lên có nhiệt độ ổn định 0°C. Khi nước đóng còn ở trạng thái lạnh và 0°C, lượng nước và rụng ở dàn căn bên kia được thấy đối với cho cảm được căn bằng.

Thí nghiệm như trên đã được tiến hành lần đầu tiên bởi George Fordyce, một bác sĩ người Anh, vào năm 1785. Thí nghiệm này đã cho kết quả quá ngạc nhiên với những phản ứng ban đầu: lý dâu trở nên nằng hơn sau khi đóng dâu hoan toàn. Rumford đã lập lại thí nghiệm trên và thấy dâu như vậy: khối lượng lý dâu đã tăng lên khoảng 0.003% sau khi đóng dâu! Kết quả này là một điều rất bất ngờ đối với Rumford vì nó đi ngược với kiến biết ban đầu của ông. Nếu chấp nhận kết quả trên thì điều đó có nghĩa rằng vật trú nên tảng trong khi mát nhiệt: hay nói cách khác, nhiệt độ khối lượng âm.

Chúa tin vào kết quả thí nghiệm trên. Rumford đã lập lại nó nhưng lần này ông không đưa vào hiện tượng nhiệt độ. Trên cơ sở biết được nhiệt độ riêng của nước lên gấp cơ 30 lần nhiệt độ riêng của thủy ngân. Ông đã khảo sát sự cần bằng giữa hai lý dâu và thủy ngân sau khi cùng làm lạnh hai lý này ở nhiệt độ ổn định 0°C. Kết quả cho thấy hai lý trên vẫn tiếp tục cần bằng (trên hai dâu căn) sau khi cùng được làm lạnh.

Quay trở lại thí nghiệm ban đầu. Rumford cho rằng kết quả đầu tiên có thể bị ảnh hưởng bởi tác động sau: hai lý dâu và hồn hợp rụng + dâu không công cụ đắc tốt nhiệt độ 0°C của phòng đã vi vậy xuất hiện các động dâu tương chống lại làm ảnh hưởng tới sự cân bằng của căn. Bằng cách cho hai lý trên cùng đạt đến 0°C trước khi căn. Rumford đã lập lại thí nghiệm đầu tiên và lần này ông không phát hiện ra một sự thay đổi khối lượng nào sau khi ly nước đóng dâu hoàn toàn.

Sau những thí nghiệm trên, Rumford đã đi đến kết luận sau: “chúng ta có thể khẳng định rằng mọi cơ gang nền xác định khối lượng của nhiệt độ sẽ không có kết quả” (“We may very safely conclude that all attempts to discover any effect of heat upon the apparent weights of bodies will be fruitless”).

Những thí nghiệm cần thận cũng kết luận của Rumford đã thuyết phorgeous hoạt hất các nhà khoa học thời bấy giờ, ngày càng những người ứng hỗ thuyết Chất Nhiệt. Từ đây, không còn ai đặt lại vấn đề xác định khối lượng của nhiệt nữa.

14. Nhiệt Sinh Ra Từ Ma Sắt

Hiển tượng ma sát sinh ra nhiệt đã được con người biết đến từ rất lâu, và đã được ứng dụng để tạo ra nhiệt hoặc lúa phục vụ cho cuộc sống con người từ những giai đoạn sơ khai. Tuy nhiên, hiện tượng sinh nhiệt này vấn là một điều bí ẩn mãi cho đến đầu thế kỷ 19, sau khi thuyết Đông Nắng đã được hoan chính.

Với vai trò là người giám sát các xung sán xuất từ khi tại Munich (Đức) thời bấy giờ, Rumford đã quan tâm đến hiện tượng tạo ra nhiệt với cương độ lớn khi các trù kim loại được khoan nóng để chế tạo sung can-nóng. Rumford quan sát thấy trù kim loại cùng các mảnh vụn của nó sinh ra trong quá trình khoan có nhiệt độ khá cao, có thể làm sôi được nước. Với thời bấy giờ, thuyết Chất Nhiệt vẫn còn đang ngứa tự, với quan điểm có lợi cho rằng nhiệt có tính bão toan. Rumford đã đặt ra câu hỏi rằng nếu có nhiệt có tính bão toan thì lượng nhiệt to lớn sinh ra trong quá trình khoan đã được lây từ đâu? Báo cáo đầu tiên về vấn đề này đã được Rumford đưa ra trong một hồi nghiên khoa học vào tháng giêng năm 1798, và đã thu hút được sự quan tâm tranh luận của nhiều nhà khoa học.

Những người ứng hỗ thuyết Chất Nhiệt đã đưa ra câu trả lời cho hiện tượng trên như sau: các mảnh vụn kim loại sinh ra trong quá trình khoan có nhiệt độ riêng hỗ hơn nhiệt độ riêng của trù kim loại ban đầu cho nên cần cù theo tính bão toan của nhiệt, nhiệt phản ứng sinh ra trong quá trình khoan!

Nhưng người đã ra giải thích trên đã không hề tiến hành một thí nghiệm chứng minh nào nên Rumford đã làm một thí nghiệm như sau: dùng nóng trong nước cho đến nhiệt độ sôi hão lượng kim loại giống nhau có cùng khối lượng, lượng thủy nhiệt là những mảnh vụn kim loại được tạo ra trong quá trình khoan còn lượng thủy hai có dạng những miếng mỏng. Sau đó bỏ hai lượng kim loại đã được dùng nóng này vào hai ống nước làm hào giống nhau có cùng nhiệt độ. Kết quả cho thấy hai lượng nước đều đạt đến cùng một nhiệt độ cao. Điều này chứng tỏ kim loại trên, cho dù ở dạng nào, cùng đều có nhiệt độ riêng như nhau.

Nhưng người ứng hỗ thuyết Chất Nhiệt sau có còn đưa ra một vài kiến giải thích khác, nhưng họ cùng chứng tiến hành thí nghiệm nào để chứng mình câu. Hiện tượng tạo ra nhiệt trong quá trình khoan còn chỉ nghiên trên đây của Rumford đã giống một dòng mạch vào thuyết Chất Nhiệt. Tuy nhiên phải đấy đến 50 năm sau, sau khi thuyết Đông Nắng đã được phát triển hoàn chỉnh, thuyết Chất Nhiệt mới đi đến chỗ phổ sanh.

15. Sự Chuyển Động Không Ngỗng của Nguyên Tử và Phân Tử

Dựa vào các thí nghiệm về sự tạo nhiệt qua ma sát, Rumford lúc đầu cho rằng bản chất của nhiệt là sự rung động của vật nóng xem như là rung động các nguyên tử chưa bền trong vật. Để kiểm chứng cho quan điểm này, Rumford đã làm các thí nghiệm sau:
Ong do vào đầy một cái bình thủy tinh trong suốt một lớp hop chất mủi có khối lượng riêng lớn hơn 1, sau đó đổ tiếp nhẹ nhàng vào bình một lớp nước tính khíệt sao cho hai lớp này dung hoa lẫn vào nhau ngay từ lúc đầu. Kể do, ong nh coke vào bình một giọt đầu- loai đầu có khối lượng riêng lớn hơn 1 nhưng phải nhỏ hơn khối lượng riêng của hỗn hợp giữa mủi trên và nước. Sau khi đổ đực vào, giọt đầu nằm ngay trên mặt phân cách của hai lớp nước và mủi [Hình 3]. Nhận do thí nghiệm đã được giữ ở nhiệt độ phòng.

Rumford lý luận rằng nếu các phần từ mủi và nước không chuyển động thì giọt đầu sẽ nằm yên mặt tại mặt phân cách: còn nếu chúng chuyển động thì giọt đầu sẽ đang dần dần nổi lên trong quá trình mủi hoà tan vào trong nước (Hình 4). Kết quả cho thấy giọt đầu nổi dần lên mạch đù khá chậm. Quá trình khuếch tán của các phần tử mủi trong nước có thể được hình dung trên các Hình 5, 6, 7.

Su khuếch tán của các phần tử mủi trong thí nghiệm trên đã đủ để Rumford giải thích theo các khả năng sau đây:
- tồn tại một lực hút nào đó từ lớp nước bên trên tác dụng lên các phần tử mủi ở dưới làm cho chúng di chuyển lên trên.
- cơ thể tồn tại sự không dòng nhất về mặt nhiệt độ trong bình chứa, làm xuất hiện các dòng dõi lưu trong bình nào các phần tử mủi đã di chuyển lên trên.
- các phần tử mủi và nước chuyển động hồn loan không ngừng nên chúng khuếch tán vào nhau.

Giả thuyết thứ ba của Rumford phù hợp với các giả thiết của chúng ta ngày nay. Tuy nhiên phải đợi đến kết quả nghiên cứu của Einstein vào năm 1905, giả thuyết trên mới được chấp nhận hoàn toàn.

16. Về Sự Tồn Tại Của Thuyết Chất Nhiệt
Ba thí nghiệm nói trên của Rumford đã làm lung lay những nền tảng của thuyết Chất Nhiệt thời bấy giờ, nhưng tài sao phải chờ đến 50 năm sau nó
mối thử sù tần lự? Có phải đó Runford không có uy tín trong giới khoa học, hoặc do tinh bảo thủ của các nhà khoa học thời đó?

Thật ra, Runford rất rất có uy tín và được ngưỡng trọng trong giới khoa học thời bấy giờ. Ông là một trong những người sáng lập ra Hội Khoa Học Hoàng Gia Anh vào năm 1800 và có những đóng góp đáng kể trong lĩnh vực khoa học. Những công trình nghiên cứu về nhiệt của ông đã được các dòng nghiên cứu sau quan tâm và truyền lan. Nếu đa giả khoa học thời đó đã thừa nhận những kết quả thí nghiệm của Runford, những người ủng hộ thuyết Chất Nhịt vẫn chưa thể từ bỏ quan điểm của họ với lý do thuyết Chất Nhịt vẫn còn đang gây rắc rối ở hiểu hiểu nhiều hiện tượng nhiệt trong khi có thuyết Đông Nang, đang trong thời kỳ phổ biến, chưa thể đáp ứng được.


17. Sự Hậu ỉ Chưa Một Lý Thuyết Sai

Vào cuối thế kỷ 18, thuyết Chất Nhịt đã đóng vai trò chủ đạo trong việc tìm hiểu và giải thích những hiện tượng về nhiệt, trong khi đó thuyết Đông Nang đang ở thời kỳ sơ khai nên nó chỉ có thể giải thích được một số ít hiện tượng.

Mặc dù thuyết Chất Nhịt đã được chứng tỏ là sai, nó cũng đã đóng một vai trò nhất định vào lúc bấy giờ. Có nhiều tính chất quan trọng của nhiệt đã được hiểu nhận vào lý thuyết này. Trong lịch sự khoa học, cũng có nhiều lý thuyết tay sai nhưng chưa bao giờ một số kết quả có ích. Ngày nay, tay bò một thời kỳ kể từ lúc thuyết Chất Nhịt được chứng tỏ là sai, chúng ta vẫn còn sử dụng đến khái niệm "động nhiệt". Mặc dù nhiệt có bản chất từ sự chuyển động hồn loan của các nguyên tử, nhiều hiện tượng nhiệt có thể đã được hình dung hồn nếu có nhiệt như là những động chảy.

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Phụ Lục: Giải triệt Nhiệt Dung Riêng và Nhiệt ấn (hoá lỏng)

<table>
<thead>
<tr>
<th>Tên chất</th>
<th>Nhiệt dung riêng C (kJ/kg. K)</th>
<th>Nhiệt ấn L (kJ/kg)</th>
</tr>
</thead>
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<tr>
<td>Nước</td>
<td>1.00</td>
<td>333.5</td>
</tr>
<tr>
<td>Rượu (ethyl)</td>
<td>0.58</td>
<td>109</td>
</tr>
<tr>
<td>Nhom</td>
<td>0.215</td>
<td>11.3</td>
</tr>
<tr>
<td>Dong</td>
<td>0.0933</td>
<td>205</td>
</tr>
<tr>
<td>Bac</td>
<td>0.0558</td>
<td>105</td>
</tr>
<tr>
<td>Thuý ngan</td>
<td>0.0333</td>
<td>11.3</td>
</tr>
<tr>
<td>Ch</td>
<td>0.0305</td>
<td>24.7</td>
</tr>
<tr>
<td>Vang</td>
<td>0.0301</td>
<td>62.8</td>
</tr>
</tbody>
</table>

Phỏng dịch từ HOW WE KNOW - Chapter 4: Is Heat a Substance? của Martin Goldstein & Inge F. Goldstein (1978)

Nhà-Trang tháng 9/95

Le Văn Hào
TOPICS FOR STUDENTS’ SEMINARS

Seminar 1:
- Theory:
The origin and the background of the Caloric Theory. Use the Caloric Theory to explain:
  - Thermal conduction
  - Thermal expansion
- Experiment:
  Compare the thermal conductivity of several metals and explain their differences basing on the Caloric Theory.

Seminar 2:
- Theory:
  Specific heat:
  - Definition and measurement
  - Explanation by the Kinetic Theory
- Experiment:
  Determine the specific heat of alcohol.

Seminar 3:
- Theory:
  Latent heat:
  - The primary notion on the melting of solid substances.
- Black's experiment on the melting of ice.
- Explanation by the Caloric Theory
- Currently accepted explanation

**Seminar 4:**

- **Theory:**
  Present the two following experiments that Rumford conducted for testing the Caloric Theory:
  - The experiment on weighing the mass of heat
  - The experiment on boring cannon

- **Experiment:**
  Examine the change of temperature in water after stirring.

**Seminar 5:**

- **Theory:**
  Present Rumford’s experiment on the continuous motion of the molecules. Analyze Rumford’s conclusions on this experiment.

- **Experiment:**
  Examine the diffusion of salt molecules into water by referring to the relevant experiment by Rumford.