A COMBINATION OF PHYSICS LECTURES AND DEMONSTRATIONS USING THE LEARNING CYCLE IN PHYSICS TEACHING AT THE COLLEGE OF GENERAL STUDIES NATIONAL UNIVERSITY OF HO CHI MINH CITY

by

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A Combination of Physics Lectures and Demonstrations Using the Learning Cycle in Physics Teaching at the College of General Studies National University of Ho Chi Minh City

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Abstract

Effective class demonstrations that capture the attention of students and make them better understand physics lectures are an important component of any physics course. There is evidence to suggest that most teachers love to watch a good demonstration but they rarely do demonstrations in their own classes. The problem seems to be that setting up demonstrations for classes is too much effort, especially at a university without a staffed demonstration facility. Moreover, an inexperienced physics instructor unfamiliar with equipment can find this part of physics teaching the most difficult to develop. Then, demonstration experiments should or should not be incorporated into the physics lectures. The answer, of course, is yes. However, the crucial problem is how to incorporate demonstrations effectively into the physics lectures.

This thesis was designed to develop an instructional model in which demonstration experiments would be combined with physics lectures by using the learning cycle. The pilot teaching of the design was implemented for a large enrollment class at the College of General Studies, Vietnam National University - Ho Chi Minh City to investigate how well students understand concepts and principles of physics, their perceptions of applying these principles into technology, as well as their attitudes toward studying physics.

More than 120 freshmen whose major is engineering participated in this study during two months in the summer session 1996. Instruments used in collecting data mainly involved teacher's and students' journal keeping, and activity sheets providing how well students understand the physics lectures and how they respond to the new method. An additional source of data included a questionnaire on students' attitudes toward studying physics. The data categorization and analysis from the sources mentioned above were implemented in general themes and the descriptive style was chosen to analyze and interpret the data.

The findings showed that students responded positively to learning physics with demonstration experiments. Students appeared to be attracted increasingly by physics demonstrations. Class discussions became more and more profound, enthusiastic, and exciting. This instructional design gave students opportunities to comprehend scientific knowledge as well as technological applications.

Dedication

To the memory of my parents

To my husband, Tran Duc Thang, and my little daughter, Tran Ha Anh

for their enthusiastic support, arduous encouragement, and unending patience

during my studies at Simon Fraser University

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Chapter I

Introduction

The setting and the problem

During the process of development, the Vietnamese educational system has been influenced by educational systems of some other countries in the world. The first influence came from China and continued into the French colonial period until the 1910's. During the French colonial period, the French established a school system in Vietnam which was mainly reserved for French and wealthy Vietnamese. This school system was the basis for public school systems in South and North Vietnam after the Second World War. In the post colonial period, there were two separate educational systems in the northern and southern regions and they both embarked on various reforms. The North Vietnamese educational system was influenced by the Soviet educational system. Therefore, the school system in North Vietnam was centralized under state control and nationalistic teachings began to appear in the curriculum. There were many changes in the South Vietnamese educational system as well. From 1954, the school system in South Vietnam still continued with the French model. Later, it was influenced by the American educational system with the use of the credit system in higher education. In 1973, there was a basic reform in the South Vietnamese educational system when American-style schools were introduced. This system was abandoned after reunification in 1975. In the post reunification period, the schools of the whole country were centralized and incorporated into the Ministries of North Vietnam. The Soviet educational system was implemented in the whole country from 1975 until the late 1980's. After the collapse of the Soviet Union, the Vietnamese educational system has been gradually transferred from the Soviet-style educational system back to the western educational system that was implemented in South Vietnam before 1975 (World Education Services, 1994).

Since the reunification, difficulties in economic development and scarcities of financial resources have faced the higher education system with serious problems. Among these has been the declining quality of education. Many educators and teachers have expressed dissatisfaction with the status of science education in particular. The most noticeable problem is that student knowledge of basic science concepts is very low. This situation is partly because science has been taught only with textbooks, blackboard, and chalk. Students have to imagine science experiments from the teacher's descriptions or from reading the textbooks. This has fostered rote learning by students and resulted in the fact that most students do not enjoy science. Students usually find science too difficult, irrelevant and uninteresting because scientific knowledge is imparted passively through the lecture method and there has not been any other supplementary method to motivate them to study science. Science programs are dominated by the textbooks published by the Ministry of Education and Training. The science content of these textbooks tends to be stereotyped, rigid and intellectually sterile. The classical lecture has been the dominant teaching method in science classrooms. The lectures usually provide little chance to foster intellectual independence. This form of teaching is boring and has discouraged students from continuing to study science. Other teaching strategies that help students thoroughly understand the science concepts, develop their critical thinking skills, and creative abilities have not had adequate attention. These deficiencies have long been a major obstacle to fostering students' scientific literacy. In 1990, to resolve this crisis in science education, the Ministry of Education and Training called for reforms in higher education. Since 1990, there have been important changes in the Vietnamese higher education system.

Since 1990, to meet the demands of developing economy and society, a plan has been developed to restructure post secondary education and to upgrade educational programs. The broad intention of the plan is to establish a "University Credit System" that gives some needed flexibility to the teaching and learning process. The credit system will allow students to have an individual plan of study depending on their learning and research abilities, to shorten the duration of study, to pursue more elective subjects, to specialize in more than one area, and to transfer easily between various degree programs and forms of education. The undergraduate programs are divided into two phases. The first phase for basic education includes the first three semesters of the academic year and is reserved for the teaching of mathematics, basic sciences, and general subjects in the Colleges of General Studies in the whole country. After the first three semesters of study in the basic education program, students who pass an examination, transfer into university for the second phase of their education. The second phase covers from five to seven semesters depending on a student's major and is reserved for the teaching of specialized and professional subjects. Students who fail this examination can transfer into technical and vocational schools. They may later continue their higher education through various forms of continuing education.

The development of this plan also led to the formation of a consortium of South Vietnamese universities to upgrade the curriculum and pedagogy in the basic sciences and mathematics in the first two years of university. This program creates good opportunities for Vietnamese science education to exchange science teaching experiences with overseas science education communities. The purpose of this program is to enhance the quality of basic science education and therefore to improve the scientific and technological literacy of the Vietnamese citizenry. This implies that the goals of science education are to provide students with a broad understanding of science and technology as well as their applications in society. This leads to the need for developing science curricula and reforming teaching strategies to reinforce the effectiveness of teaching and learning. New curricula in the fields of natural sciences, engineering, agriculture, and management were proposed in the 1987-88 academic year. New textbooks were prepared and systematically edited in 1990 (Thac Can, 1991). Although many efforts have been made, textbooks and teaching methods which reflect current understandings in science are still lacking. The quality of textbooks also needs to be continuously improved. Apparatus and equipment for laboratory instruction are very scarce in most universities. This results in a science education which relies on rote memorization and routinization.

Reforms in higher education in Vietnam are still in process in the whole country. In South Vietnam, the reforms began with the establishment of the Vietnam National University-Ho Chi Minh City on the basis of the rearrangement and the reorganization of nine Universities at Ho Chi Minh City in January, 1995. However, at present, the innovation is only the formation of the new university structure accompanying the application of the credit system. Textbook revision has begun, but the reforms in methods of teaching have been minimal. The dominant method of teaching in the most Vietnamese universities has been the direct teaching (lecture method) in which the role of teachers is to impart knowledge to students through lectures. The lecture method is the most frequently used method for instruction in the college classroom. This method can be used effectively to summarize the results of a large number of studies and theories. That is one of the most time effective ways of imparting knowledge for a large class of students but it usually encourages students to receive knowledge passively. According to Ekeler (1994), the lecture method is somewhat inferior in comparison with other teaching methods in developing student's problem-solving skills and it is not well suited to the development of high-level intellectual skills and attitudes. The direct teaching method, like any other teaching method that is poorly implemented, can lead to rote learning. Rote memorization is probably better for learning "science facts," since these are much more straight forward. However, the most important fruits of science learning are not only the science facts, but also scientific concepts and laws, attitudes toward science and motivations to study science. The lecture method would be more effective if it were combined with demonstration experiments, especially in physics teaching. These demonstrations would facilitate students' acquisition and retention of science knowledge and concepts through activities such as observing and explaining physical phenomena. The "meaning" of science concepts is learned through applying them to explain phenomena. When concepts are used in the explanatory "world," they are thoroughly understood. For this reason, the combination of lectures and demonstrations plays a crucial role in science teaching. Actually, lecture demonstrations have long played a part in science teaching of all kinds, whether at universities and technical colleges, schools or in special lectures organized by various groups. In his article, "Students in small colleges also benefit," Hudson (1970) wrote:

> Since physics is an attempt to understand phenomena, I feel that demonstrations are an indispensable part of the tactics of teaching physics. Too few students have trained themselves to be sensitive to the varied happenings of nature. Demonstrations can make more acute this sensitiveness which is certainly a useful attribute of the scientific attitude. (p. 9)

In science teaching, demonstration experiments should be incorporated into lectures to teach in a way that gives students a clear understanding of the linkage between theory and experiment - an understanding of science itself. Through demonstrations, students may be led to make connections between the phenomena and theoretical concepts by which they describe and codify related happenings.

Many teachers feel that lecture demonstrations are an effective way of teaching, but there have been few evaluations of the method. It is much more likely that a student will remember a well-executed demonstration experiment than an elegant derivation of an important equation. The following extract from an article titled "An effective teaching method" provides support :

> In talking to old graduates, who now have occupation quite removed from the application of physics, they remark that they often recall their physics through their memories of physics demonstrations that they had seen in a physics course. We like to think that recall such as this is also used extensively by engineers and scientists. (Freier, 1970, p. 9)

It needs to be recognized that the purpose of a physics lecture demonstration is not to convince the students that a physical principle is valid but rather to leave the students with a memorable impression of how some principle can be used to explain a phenomenon. The lectures with demonstrations will give students opportunities to understand how a professional physicist thinks about a topic or develops it from first principles and primary phenomena. This makes students accustom to thinking like a physicist, a skill some students find difficult to develop.

The lecture demonstration is not a new approach in science teaching, its use was developed from the seventeenth century. However, the role of demonstrations in student learning is still appreciated through some evaluation results from the Introductory University Physics Project (IUPP) executed during two academic years (1991-1992, 1992-1993) in nine colleges and universities in the United States. The preliminary IUPP results showed that: "when demonstrations of physical principles were performed in class, they were consistently mentioned as a positive aspect of the course" (Stefano, 1996, p. 59). Moreover, in the present context of science teaching in Vietnam in which the direct teaching method is being used widely in the whole country, it is expected that the combination of demonstration experiments with science lectures would produce more fruitful results.

The purpose of the study

The purpose of this thesis is to develop an instructional model for physics education in the first three semesters of the College of General Studies based on lecture demonstrations. It is hoped that this change will support a deeper understanding of basic science, and improve comprehension of simple technological applications, while engaging students actively in studying physics. To design this model, the learning cycle described by Robert Karplus (1977) will be used to combine lectures with demonstrations. This study seeks to investigate the following questions:

1. How students understand concepts and principles of physics through 3 phases of the learning cycle?

2. Students' perceptions on the relationship between fundamental principles of physics and technological applications?
3. Affective aspect of students' attitude toward studying physics?

It is my thesis that the application of the learning cycle into lecture demonstrations will improve the quality of science education in the following specific ways:

- Students will develop better interest and greater involvement in science through lecture demonstrations.
- Students will be provided with greater opportunities to understand how science principles operate and the ways the scientists think. That is one of the goals of science education. This goal, if achieved, will better equip students for further study.
- Demonstrations which relate to technological applications or the role of science in everyday life will enhance students' understanding of technological issues. Academic preparation will no longer be the dominant goal of science education. The new goals for science education should be balanced between academic preparation, technological issues, and career awareness.

This approach to the teaching of science is relevant to the current period of innovation in higher education in Vietnam. It will contribute to upgrading the curriculum and pedagogy in physics teaching in my college. By helping students understand physics better and by motivating them to study physics through demonstration experiments, I hope that their interest and talents will be developed for further study. Their positive attitudes toward science and scientific literacy would also be enhanced.

Significance of the study

At present, Vietnamese higher education is in an innovative phase. Therefore, the need for revisions in science curricula and reforms in teaching methods can be seen as a crucial problem. This study will play a small part in this innovation process. The combination of lectures and demonstrations using an effective model of instruction may assist students in enhancing their understanding of basic science knowledge. The findings of this study might provide a general view and information about students' background before the course, and portray a picture of the evolution of students' understanding of physical concepts and principles. By getting involved in learning activities with demonstrations and the learning cycle, students' attitude toward studying physics will be developed. The study might reinforce Vietnamese teachers' perceptions of the necessity of lecture demonstrations in basic physics courses and provide a good source for them in order to make decision on what demonstrations should be taught and how they should be taught. Furthermore, this study may promote science educators in revising and modifying the goals of science education. Hopefully, the study will encourage science teachers to improve and enhance the quality of science teaching in my college.

Limitations of the study

The results of this study are derived from a small sample including more than 120 students of the total of approximately 4,000 students who major in engineering in the College of General Studies, VUN-HCMCity. Moreover, as discussed more fully in chapter 3, this study was conducted in the summer session when average and poor students are the classroom majority. Therefore, the results should not be generalized to a large general student population. The findings of the study were drawn partly from students' journal. However, the 10% of students who volunteered to keep journals were largely fairly good and near average students, who were a minority in the class (14%, see table 1, p. 34). This situation might result in some biases in the findings. Another limitation of the study is that the questionnaire assessing students' attitudes toward studying physics was administered once at the end of the course, when students' interests had reached the highest level. This fact may influence the study results. Additional, because the investigator was also the instructor, some bias may exist in reporting the results and designing sampling instruments.

Chapter II

Review of Related Literature

The history of lecture demonstrations.

The lecture demonstration method of instruction was already popular in the seventeenth century. The Royal Society was founded in 1660 and appointed Robert Hooke as its first curator and demonstrator in 1662. He provided new experiments for most every occasion the Royal Society met.

Desaguliers (1683-1744) can be considered as a pioneer in popularizing demonstration lectures. Also a curator of experiments at the Royal Society, he wrote: "Without observations and experiments, our natural philosophy could only be a Science of Terms and an unintelligible jargon" (Taylor, 1988, p. 2). His book is a marvelous compilation of demonstrations, many of which could be set up and used very effectively in the present day. According to Desaguliers, the first person to give public demonstrations as part of a course of instruction was John Keill (1671-1721). He began a series of experimental lectures on Newtonian Philosophy in 1694.

By the middle of the eighteenth century, the lecture demonstration had become widespread in England. At that time, there were peripatetic lecturers who took round scientific apparatus and lectured at various centers.

In the nineteenth century, many remarkable demonstrations had been developed, for instance, Young's fringes, Young's color patch experiments, Tyndall's demonstration on sound, Faraday's demonstration on electrostatics (Faraday cage), and so on. Science had become a matter of wide public interest. It became fashionable to perform scientific experiments at the dinner table.

In the last half of the nineteenth century, many questions about the effectiveness of popular science lectures were raised. In 1881, Galloway wrote:

> I can assure you there is nothing more difficult for a teacher to accomplish than to educate those who have been previously superficially taught. The most difficult to teach I have found, as a rule, are those who have been accustomed to attend popular science lectures; for what they hear is generally very superficial; and, therefore, what they acquire must be superlatively superficial. (p. 53)

Such opponents felt that the demonstration was, at best, a waste of time and that, at worst, it could be harmful to the educational process. However, lecture demonstrations remained popular both at school and university until the Second World War. After that, there was a decline of the art of experimental illustrations in universities, especially in the more advanced lectures: "When I was a student, the lecturer did many experiments and they were very important to us; I remember them vividly. Now the classes are so large and the lecturers are so busy that they do not seem to be able to arrange experiments which take much time to organize. This decline has been the subject of general comment, and it is very probable that a firm move will be made in the near future to reconstitute more demonstrations to classes" (Bragg, 1970, p.13).

The causes for the decline in using lecture demonstrations was a mixture of many factors:

> The growth of scientific knowledge was explosive and more and more material was crammed into the curriculum so that teachers and lecturers tended to feel that it was a waste of valuable time to interrupt their classes by doing experiments; technical assistance was more difficult to obtain; there was less money available to purchase increasingly expensive equipment and in universities the "publish or perish" principle in determining eligibility for promotion meant that lecturers tended to regard time taken from their research to develop demonstrations as time wasted. Furthermore, many of the more recent discoveries in a subject like physics

> are impossible to demonstrate because of the scale and cost of the apparatus needed or because of the hazards of the experiment. (Taylor, 1988, p.4)

In Taylor's opinion, there were many contradictory developments in lecture demonstrations in the twentieth century. On the one hand, some of the most exciting developments in technology such as laser light sources, oscilloscopes, and other lab equipment have become available to enhance demonstrations. But, on the other hand, shortage of time and of technical assistance have reduced the opportunities for demonstrations in public schools and university classes.

The supporters of Amstrong's heuristic method tended to imply that demonstrations were of little value compared with laboratory experimentation by the students themselves.

> Laboratory work, because it involves the individual directly in the learning process, as well as imparting working skills, is thought to be superior to teaching by demonstration. A person working on a laboratory problem has learned far more than just the answer to the problem. He may be efficient, self-reliant, and analytical; to observe, manipulate, measure and reason; to use apparatus; and most importantly, to learn on his own. Individual laboratory experimentation helps to attain these goals better than demonstrations do. For this reason, demonstrations should play a lesser role in science instruction, with individual student investigation receiving top priority. (Trowbridge & Bybee, 1994, p. 232)

Taylor agreed with the idea that pupils and students should do experimental work themselves. But he thought that practical work in the laboratory and lecture demonstration are not mutually exclusive and really fulfill complementary functions. According to Jenkins (1979), reports that were published by the Science Masters' Association after the Second World War advocated the use of demonstration experiments in teaching science. In 1950, another report was published to indicate that this advocacy did not imply that demonstration experiments could replace laboratory work done by students for themselves.

Why lecture demonstrations should be taught.

In the lecture method, there is a severe problem of lack of communication between teachers and students. When the teacher wants to make students understand concepts by putting them into words, diagrams, or symbols, the students take note of the words and from these they build up a meaning. There is clearly a strong possibility that the meaning created by the students is not the meaning meant by the teacher. This possibility is high if the type of language used by the teacher is not similar to that of the students. This problem can be reduced by lecture demonstrations. Through lecture demonstrations, students have a direct intuition about the meaning of the concepts that the professor wants to convey. According to Taylor (1988), when a teacher lectures, he or she is acting as an information-transmission system and can affect the quality of information transmitted all too easily. Even though he or she knows his subject and can explain it clearly, the students can only perceive, and that act is a kind of aperture which may modify, restrict or even falsify the information. Therefore, the teacher is in a enormously powerful position of influence, and has a responsibility to make the efficiency and accuracy of students' learning as high as possible. This is an important justification for using demonstrations. Students can relatively easily misunderstand words or a whole sequence of ideas; if the point is well illustrated by a demonstration, the chance of imperfection in the information transfer is greatly reduced.

Talking a broad perspective, our teaching duty goes far beyond supplying information. It is concerned with conveying to students the nature of science: what it is, how it is done, how it grows in strength of knowledge, and even where it may lead. In this context, demonstration experiments can play an important part in the accomplishment of that duty:

> In addition to factual information, demonstration lectures can convey the essence of scientific experimenting and reasoning - quickly, capably, and with compelling interest. Our science, in contrast with pure logic and mathematics, is necessarily connected by experiment with the world we live in. In building our knowledge of physics, there is also reasoning and speculation; but our knowledge as a whole keeps its feet on the ground by typing both the initial assumptions (our building bricks for models) and the final predictions (our explanations) to experiment. Therefore, in the rapid, compact setting forth of our science which we carry out by lectures, there must be demonstration experiments if we are to give our young students genuine understanding. It is only at later stages of learning, when both basic knowledge and a framework of understanding are established, that we may reduce most experiments to descriptions at second hand, to be taken on faith by neophyte scientists. (Rogers, 1970, p. 43)

At the undergraduate level of examinations, according to Freier (1981), it is easy to find that some students can use an analytical approach to do quite well with quantum mechanics problems. But they maybe fail miserably if they are asked to solve problems in mechanics where they must discern the differences between elastic and inelastic collisions. In this case, they can not differentiate well between acceptable and ridiculous results. This aspect was analyzed by Freier (1981) as follows:

> With no time wasted on a demonstration, the teacher can sketch a ball at the end of a spring and proceed to show all of the elegant analytical solutions. Symbols in the equations can be identified with parameters in the drawing. This procedure should allow one to use a mass of one kilogram and a spring constant of 10^{-4} newtons per meter. In real life these numbers would never appear together. How much better it would be to have a one-kilogram mass and a few different springs on a support. If we are to observe oscillation at all, using real bobs and springs (which also have mass), the spring constant must be greater than about one newton per meter. It is just as important to recognize a ridiculous situation as it is to know the method of analysis. The analytical method does not lead to the recognition of physical reality. Similarly, the physical feeling that one can gain from seeing springs connected in series and in parallel can add a lot to remembering whether one should be using addition of reciprocals of spring constants or whether one should be adding spring constants. (p. 385)

Students usually enjoy demonstration experiments, because they are fun to see and fun to do. A good demonstration experiment not only gives a better understanding of physics, but also makes the study of physics "fun" for the student as well as for the teacher. This is of genuine value. Moreover, demonstration experiments are part of our knowledge; therefore, the teachers should enliven lectures with experiments.

However, demonstrations are an expensive way of conveying knowledge in terms of time as well as equipment and personnel in comparison with the lecture method. If "a picture is worth a thousand words," then "a demonstration should be worth ten thousand." Demonstrations help students develop an intuitive feeling for the real world, for how things work. They increase students' understanding of basic concepts; they encourage students to attempt some of demonstrations on their own; and they stimulate discussion among the students. It is fully relevant to give students lectures with demonstrations because they deliver the knowledge clearly and simply. Actually, Black (1930) implied that demonstrations were needed to arouse interest in the students and to make the subject clear. According to him, it is difficult for students to comprehend physics concepts, therefore demonstrations helped students visualize those concepts.

In addition, many teachers felt that the demonstration was a great time saver and requires less equipment and fewer materials in comparison with individual laboratory work. In contrast, as mentioned in the previous section on the history of demonstrations, some educators tended to imply that demonstrations were a waste of valuable time and were of little value compared with laboratory work. Some educators, for instance, Carpenter (1925), investigated the relative merits of the individual laboratory and the demonstration method in chemistry and concluded that at least some laboratory work should be replaced by teacher demonstrations. He did not believe that all individual laboratory work should be eliminated nor that schools in the future should be built without laboratories, but he did think that more of the present laboratory exercises should be conducted by the teacher as demonstrations and only a few by the students themselves. Similarly, the thirty-first NSSE Year Book committee concluded that "in the interests of economy both of time and of money, it seems desirable to perform more laboratory exercises by the demonstration than by the individual method" (National Society for the Study of Education, 1932).

What lecture demonstrations should be taught.

General speaking, a demonstration means the illustration of a point in a lecture or lesson by means of something other than conventional visual-aid apparatus (such as the use of slides or films). In his book on the art and science of lecture demonstration, Taylor (1988) divided demonstrations into three categories: visual-aid using non-conventional apparatus, analogue demonstrations, and real experiments.

Visual-aids using non-conventional apparatus

One of the examples of this category is the use of striped strings to help students understand the concept of the limit of resolution in an optical system or the use of wire models to illustrate interference effects in polarized light in which the two wire sine waves are connected together at the zero displacement points by small rubber bands. Another example is the use of a "tinker vector" to help students visualize the spatial aspects of problems relating to Gauss's law and its applications.

Analogue demonstrations

Analogue demonstrations use a phenomenon whose behavior is sufficiently similar to that being discussed to make it valuable as an instruction aid. An example of the second category of demonstrations is the use of optical analogues to illustrate X-ray diffraction. In this case, X-ray demonstration (the phenomenon being discussed) is not easy to demonstrate directly because X-ray are both invisible and dangerous. However, with a suitable change of relative scale of the object and of its nature, many of the phenomena of X-ray diffraction can be demonstrated to students.

Another example is the analogue demonstrations of Ampere's law and magnetic flux that were carried out by Peter Heller in the Department of Physics, Brandeis University in 1991. These demonstrations help students develop a visualization of field concepts and relations and deepen students' understanding of the electromagnetic laws through the abstract concepts such as "line integrals" as well as "flux."

Real experiment

The third category of demonstrations is real experiments in which the actual phenomena being discussed are portrayed, such as the experiments on the spectrum transmitted by a colored transparent object, double-slit interference, single-slit diffraction. Another example is the experiment for observing ferromagnetic phase transition. Real experiments usually involve both quantitative and qualitative aspects of physics experiments. Quantitative experiments require greater precision of measurement and accuracy of results and are often used in the laboratory. Qualitative experiments address the qualitative characteristics of the physical phenomena and are often used in lecture demonstrations.

The use of this category or others depends on the subject matter that needs to be demonstrated. The development of a demonstration should focus on one or more of these aspects:

1. Clarifying the conceptual problems such as the notion of charge, field, flux, line integral, and similar concepts through demonstrations developing a visualization of these concepts. When students start the study of electricity, the troubles of more abstract thinking became more apparent. Many students would have much more difficulty with electricity because they could see the effects of "electric charge" and " electric field" only through the behavior of electroscopes. On the other hand, it is usually hard for them to understand the physical meaning of abstract mathematical concepts which is a difficult point in the basic physics curriculum. Demonstrations need to put concepts that are abstract into a concrete and practical form. The category of analogue demonstrations usually expresses its merits in this case. Analogue demonstrations take abstract principles and put them into concrete actions which are more believable and easier to comprehend.
2. Developing the intellectual skills such as careful observation, the ability of creative and critical thinking, objective evaluation of evidence, the ability to draw inferences from data through demonstrations of principles or laws in physics and the ability of solving problems. Such demonstrations are usually real experiments that will stimulate students' curiosity, inquiry and logical analysis. The development of these

intellectual skills is very important since scientific thinking provides an effective way of dealing with students' everyday world.

3. Understanding technological applications and their relations to the fundamental principles of physics. According to the new trends in physics teaching, physics teachers should not restrict their attention to the teaching of pure science because "Ignoring technology when teaching sciences is like establishing the foundations, and sometimes the skeleton of the house, without demonstrating what a useful building it could be" (Waks, 1994, p. 65). Therefore, lecture demonstrations should be both physics-oriented and technology-oriented since science and technology are intimately linked, and understanding of scientific concepts can and should be greatly enhanced by the demonstrations of technological applications. The applications of science are used to motivate students and to demonstrate how science functions in our world. For example, the application of the property of conductors in the external field (conductors have no internal static electric field) can be demonstrated to help students understand the principles of "shielding" electrical equipment by placing it in a metal can. The purpose of this orientation is to enhance students' ability to apply knowledge and thinking skills in solving new problems that they maybe confronted in their future career.

It often takes more of a teacher's time to prepare a lecture which includes demonstrations. In fact, teachers feel that they cannot cover as much material if demonstrations are included in lecture. It is really not necessary for the teacher to make a complex demonstration that takes much time to prepare. Demonstrations should be offered in a simple but meaningful way. If demonstrations are simple and if they are well chosen, then the teacher can lead his or her students to a better understanding of the ideas being presented.

How lecture demonstrations should be taught

There are two main approaches of presenting demonstrations. Some teachers use demonstrations to show the experimental basis of physics using an inductive approach. Those who advocate this approach, pay much attention to portraying science as a process of investigation and teaching students how to experience the processes of scientific thinking and investigation. While this approach is valuable in providing students with facility in scientific thinking, it overemphasizes the importance of science processes at the expense of the teaching of content.

In contrast, others who master the teaching of a well-organized deductive development prefer to offer demonstrations as illustrations of a principle or law. This fact reflects two different teaching strategies: inquiry (inductive) teaching and expository (deductive) teaching. According to Tanner (1969), an inductive or discovery method "is intended to enable the learner to discover or construct principles or concepts, by interacting with instances of those principles or concepts." The focus of the inquiry teaching procedure is to represent science as a processing of scientific phenomena (Marek, Enbanks, & Gallaher, 1990, p. 822). In contrast, a deductive or expository method "is one in which the principle or concept is presented to the learner prior to his working with instances of it" (p. 647). Expository teaching procedure portrays science as a body of knowledge, consisting of facts, laws, principles, and theories (Marek, Enbanks, & Gallaher, 1990, p. 822).

Novak (1979) also made a distinction between two approaches: reception and discovery learning. According to him, reception learning is a kind of learning "where the regularities to be learned and their concept labels are presented explicitly to the learner." Discovery learning "requires that the regularities in objects and/or events are first discovered by the learner" (p. 483). Novak also emphasized that there was a continuum from pure reception to pure discovery learning and that most discovery learning was actually a kind of "guided discovery." Guided discovery is a form of teaching in which the teacher activates students' mental operations to lead them to make "discovery" by organizing instructional activities. Kaufman (1971) implied that discovery learning is the most effective way to learn because what is self-learned is best learned.

A number of studies were carried out to compare the effectiveness of the inductive and deductive approaches. However, the results that were obtained from these studies were generally inconclusive:

> Research studies conducted during this time period on the comparative effectiveness of inquiry and non-inquiry strategies were generally inconclusive. Teachers who chose to use one method over another did so because of personal success with the method or because of a faith in the ultimate superiority of that method. Education research was unable to offer a definitive answer to the question of which was more effective or which had greater educational value. (Deboer, 1991, p. 213)

Each of these strategies has its own merits for particular circumstances. The use of one or the other is each teacher's own choice so that his or her teaching comes completely from his or her own heart. In my opinion, the strength of the inquiry teaching is the stimulation of the student's creative and independent thinking. Its weakness is its time consuming character, and therefore this teaching method tends to reduce the amount of knowledge that can be conveyed to students. The teachers should be encouraged to use inquiry teaching but there is need for balance between the available time and the amount of knowledge conveyed to students. This depends so much on the teacher's capacity and enthusiasm.

Learning cycles: A better way to incorporate demonstrations into physics lectures

In my college, it seems to me that introductory physics courses have been characterized as boring and irrelevant to students. Most teachers think that students' minds are like empty vessels and that they need to be filled with large amounts of knowledge. This knowledge is often memorized and then quickly forgotten. Therefore, science teachers should choose instructional models that facilitate students' acquisition and retention of knowledge. Lecture demonstrations can be seen as a positive aspect of physics teaching, but it requires a relevant model of instruction. On the basis of reviewing available instructional models, it can be recognized that one of the significant models of instruction that can be used to effectively incorporate demonstrations into physics lectures is the learning cycle offered by Robert Karplus and his colleagues. This model of instruction was developed originally as part of the Science Curriculum Improvement Study (SCIS) and has been used at all levels of science education from elementary school to university in the United States. According to Zollman (1990), the learning cycle has been used successfully for small-enrollment physics classes at several institutions, including the University of Washington in Seattle, Fairleigh Dickinson University, and the University of Nebraska at Lincoln. However, in his experience, the learning cycle can also be adapted for large-enrollment classes:

> At Kansas State University we are required to teach the physics course for elementary-education majors in one large section. (The enrollment is approximately 100 students per semester.) Thus, the methods of the learning cycle had to be varied to fit the requirements imposed by one large class.

> To adapt the learning cycle for a large-enrollment course taught by a single faculty member, we use a combination of activities completed in an open laboratory environment and large class meetings. (p. 21)

The learning cycle is based on Piaget's theory of intellectual development with the purpose of encouraging students to use their mental processes of concept acquisition and problem solving to enhance the effectiveness of their learning. It can be used in designing curriculum materials as well as instructional strategies as indicated by Renner, Abraham, and Birnie (1988): " The learning cycle is a method of teaching - it is also a curriculum organization principle" (p.39).

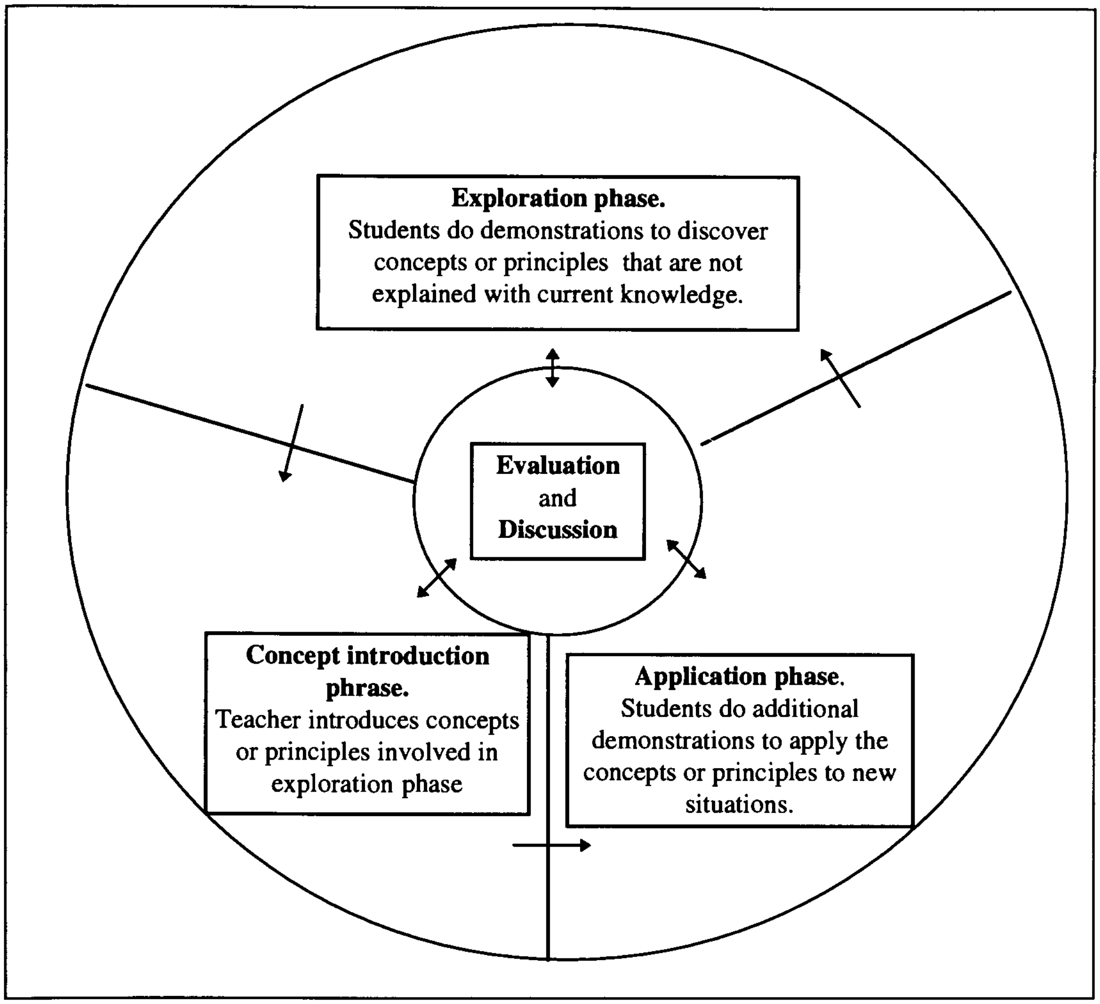
Piaget has characterized human intellectual development in terms of four stages: sensory-motor, pre-concrete operational, concrete operational, and formal operational stage (Inhelder & Piaget, 1958). The first two stages are usually completed when a child is seven or eight years old, the last two stages are relevant to secondary school students (Karplus, 1977). In 1964, Piaget identified four factors that affect the process by which a person advances from one stage to the next. Those are maturation, experience, social communication and equilibration. Maturation implies the process of physiological development. Experience refers to the process of personal interaction with one's environment including physical experience (drawn directly from objects), and logical-mathematical experience (drawn by actions which affect objects). Social communication deals with social transmission or direct instruction that requires the personal capability of communicating information via written and oral language. Equilibration, or self-regulation, is the process whereby a person is first confronted with new experiences that conflict with ideas he or she previous held and afterwards transforms new knowledge to fit into his or her existing mental structure. The second and the fourth factors are more important when applied to university students.

In an attempt to understand the world, the human being usually uses repeatedly an invariant process called mental functioning. According to Piaget, the process begins with the learners' assimilation or transformation of the data from their environment into their mental structures. Mainly the learners must assimilate the data by themselves. No one can assimilate for them. The data are then processed and this results in the changes in the mental structures. This process is called accommodation by Piaget. During the process of changes in the mental structures, the learners usually experience a state of disequilibrium. When the learners' mental structures have accommodated to the assimilated data, they would reach a state of equilibrium.

> Curriculum materials and instructional strategies which are compatible with Piaget' s ideas would give students the opportunity to assimilate information by exploring the learning environment, accommodate that information by developing a concept to explain or organize the information, and organize or relate the new concept to existing knowledge by using or expanding the new concept to explain different phenomena. (Renner, Abraham & Birnie, 1988, p. 40)

The learning cycle includes a set of instructional steps related to Piaget's notion of cognitive development. It is an attempt to provide the necessary experience and self-regulation. The learning cycle consists of three instructional phases that combine experience with social transmission and encourage self-regulation (SCIS, 1974). According to Karplus, these three phases are exploration, concept instruction, and concept application.

During the exploration phase, students are encouraged to learn through their own actions and reactions in a new situation. Activities in this phase help students recall past experiences or assimilate new experiences useful for the later phases. They are provided with chances to explore new phenomena, new ideas, and relationships with minimal guidance from the teacher. The new phenomena raise questions or problems that students cannot solve within their present conceptions and accustomed patterns of reasoning. As a result, mental disequilibrium will appear. In this case, the teacher should maintain an appropriate level of disequilibrium to prepare students for self-regulation. This phase involves the spontaneous process of exploring new ideas. The exploration activities supply the teacher with information concerning the students' attempts to deal with the concepts, and skills being introduced. Therefore, through this phase, the teacher can evaluate students' understanding and background related to the intended outcome objectives. These activities also help students develop their interests and stimulate their curiosity. This results in the reinforcement of students' observation ability, critical thinking and scientific reasoning skills.



Exploration phase.
Students do demonstrations to discover concepts or principles that are not explained with current knowledge.

Concept introduction phrase.
Teacher introduces concepts or principles involved in exploration phase

Application phase.
Students do additional demonstrations to apply the concepts or principles to new situations.

Figure 1: The learning cycle

The second phase is the concept introduction (or term introduction in Lawson's terminology). This phase provides social transmission and starts with the definition of a concept or principle (or a term) used to label the pattern discovered during the exploration phase. The teacher gathers information from students about their exploration experience and uses it to generalize concepts, to introduce principles, or to supply an extension of students' skills or reasoning. Students are encouraged to formulate relationships which generalize their ideas so as to be consistent the outcome objectives. This phase usually follows the exploration phase and relates directly to the pattern discovered in the previous phase. Students should be encouraged to recognize as much of a new pattern as possible before the concept introduction. Of course, they can not recognize all of complex patterns. This process helps students "self-regulate" and move toward the state of equilibrium whereby the concepts or principles introduced have just been assimilated and accommodated. This phase requires much more the teacher's guidance, whereas the exploration phase was minimally teacher-directed.

The last phase is concept application that allows students to apply the new concept reasoning pattern to new situations. This phase helps students extend the range of application of the new concepts or principles. The application activities allow additional time for accommodation required by students needing more time for self-regulation. It also provides additional equilibrating experiences for students who have already accommodated the concepts or principles introduced. At the end of this phase, the teacher can evaluate how well students generalize and transfer ideas they just learned to new applications.

Lawson (1988) clarified the meaning and the relationship between the three phases of the learning cycle as follows:

> The last phase is referred to as concept application, while the previous phase was labeled term introduction. A concept is defined as a mental pattern (i.e., a pattern in one's mind) that is accessed by a verbal or written symbol (i.e., a term). Therefore, a concept is the recognized pattern plus the term. A person can have the pattern or the term but he does not have the concept until he has both. Teachers can introduce terms to students, but students must recognize the patterns themselves. Exploration provides the opportunity for students to discover the pattern. Term introduction allows the teacher to introduce the term that refers to the pattern. It provides students an initial opportunity to link the pattern with the term and thus acquire the concept. Finally, concept application allows students repeated opportunities to recognize the pattern and/or to discover applications of the new concept in the new contexts. (p. 269)

Lawson also differentiated three types of learning cycles: descriptive, empirical-inductive, and hypothetico-deductive. All of these have the same sequence of activities as described above. The basic difference between them is the degree which students either gather data in a descriptive manner or begin to test hypotheses in a controlled manner.

The descriptive learning cycle merely requires students to describe what they observe without attempting to generate hypotheses to explain their observations. In the exploration phase, students explore the phenomenon and try to discover and describe the pattern. During the term introduction phase, students report the data they gathered and describe the pattern. The teacher then introduces the term referring to the pattern. In the concept application phase, students identify the pattern in additional contexts.

The hypothetico-deductive learning cycle begins with the teacher's statement of a causal question. This question can be raised by students through exploration activities. They are asked to answer this question by generating possible hypotheses. In the exploration phase, students deduce the logical consequences of these hypotheses and do some experiments to test them. In the term introduction phase, the gathered data are compared and analyzed to draw needed conclusions. From the analysis of experimental results, some hypotheses may be rejected and some can be retained. In the concept application phase, additional phenomena that involve the same concepts and reasoning patterns are discussed or explored. In terms of student reasoning, the hypothetical-deductive learning cycle requires the use of higher-order patterns such as controlling variables, correlational reasoning, hypothetico- deductive reasoning.

The empirical- inductive learning cycle also begins with the teacher's raising a descriptive and causal question. Students are asked to do experiments to gather data for answering the descriptive question, and then to induce alternative hypotheses to answer the causal question. This exploration phase requires students to discover and describe an empirical pattern in a specific context and then generate possible causes of that pattern. In the term introduction phase, the patterns that relate to the explored phenomenon and most likely hypothesized explanation are transferred to the new context by using analogical reasoning. In the concept application phase, students examine carefully the gathered data during the exploration phase to see if the hypothesized causes are consistent with those data and other phenomena. This type of learning cycle requires descriptive reasoning patterns in observations but involves some higher-order patterns in going further to generate and test causes.

Depending on the nature of subject matter that needs to be conveyed to students, the teacher can choose one of these three types of learning cycles. The learning cycle model establishes a teaching-learning format which is based on the processes of intellectual development. Its major goal is to assist the students' general intellectual development as well as to improve their scientific knowledge. This goal can be reached when the student rather than the teacher becomes the center of the learning process.

As mentioned earlier, many educators emphasized the positive role of lecture demonstrations in science teaching. Many articles on why demonstrations should be taught have been found in some journals of research in science teaching. The book "The art and science of lecture demonstration," written by Taylor and published in 1988, discussed various aspects of lecture demonstrations. Taylor differentiated between 3 types of demonstrations and offered many examples of physics demonstration experiments corresponding to each type of demonstrations. How lecture demonstrations should be taught was disputed by several educators for many years. Some teachers would like to offer demonstrations as illustrations to verify principles or laws. Others prefer to present demonstrations using the inductive approach. However, a number of research in science teaching that were implemented to compare the effectiveness of these two approaches were generally inconclusive, as indicated in the previous section.

As an effort to contribute to how to teach more effectively physics with demonstrations, this study attempts to organize physics lectures and demonstrations into the learning cycle by integrating demonstrations into the first and the last phases, and physics lectures into the middle phase. This integration is feasible because the learning cycle is not a merely teaching method, it can also be used to design curriculum materials. This characteristic of the learning cycle makes it possible to be utilized to incorporate demonstrations into physics lectures by designing a curricular model in which demonstrations and physics lectures are arranged and organized appropriately into 3 phases of the learning cycle. Such curricular model can be probably implemented because the learning cycle is a very flexible model of instruction.

Chapter III

The design of the study

The context of the study

An overview of the setting

In order to proceed with the reforms in higher education, the governmental Prime Minister signed a "Decree 16/CP" to establish the Vietnam National University - Ho Chi Minh City on Jan 27, 1995. In accordance with the Prime Minister's authorization, the Minister of Education and Training signed the Decision # 2262/GDDT on July 4, 1995 to establish an executive committee with the responsibility of organizing and constructing the College of General Studies. The CGS was formed on the basis of the integration of the departments of Basic Sciences and Mathematics from the University of Technology, The University of Technical Teacher Training, the University of Agriculture and Forestry, and a part of the department of Social Sciences and Humanities of the University of HCM City. On March 5,1996, the Minister of Education and Training authorized the CGS to operate as part of the VNU-HCMCity.

The CGS has two campuses. The main campus with its administrative offices and academic departments is located on 800 hectares of the National University area at Thu-Duc District, fifteen kilometers from the center of HCM city. The second campus is located at the B_4 building, College of Technology, District 10, rather near the HCM city center. The CGS is given the responsibility of training university students in the first three semesters of the undergraduate programs (the first stage). The College offers basic courses in Natural Sciences, Social Sciences and Humanities, Foreign Languages, Physical Education, and Military Education. In the first academic year 1995-1996, more than 6,000 students enrolled in this college. These students had passed the national university entrance examination into some colleges of the VNU-HCMCity including College of Technology, College of Technical Teacher Training, College of Agriculture and Forestry, and College of Humanities. It should be noticed that before applying for taking this entrance examination, students are required to choose the field of study that they would like to pursue in the second stage. The CGS only trains about 40% of the total of first year students belonging to the VNU-HCMCity. The remainder includes 60% of students who choose their field of study in the other 6 colleges. These students take basic courses of the first stage of undergraduate programs at these colleges. In the academic year 1996-1997, the total enrollment was about 12,000 students.

In higher education in Vietnam, the duration of training is divided into two stages: the stage of general studied and the stage of professional studies. For the first stage, students are provided with basic knowledge corresponding to seven academic programs to assist students in pursuing their major in the second stage. Students have to choose one of the seven programs and within each program they take core courses and some elective courses. These seven programs include: program 1, 2, and 3 offered for students whose interest is natural sciences or technology. Program 1 emphasizes mathematics and physics, program 2 focuses on chemistry, and program 3 concentrates on biology. Program 4 enrolls students who would like to major in economics and business administrations. Program 5 is designed for those who are interested in social studies, program 6 for humanities, and program 7 for foreign languages.

Students have to spend three terms to finish one of the seven academic programs of general studies. Students are required to complete at least 90 credits in the first stage (one credit is equal to 15 lecture hours or 30 lab hours). Those who obtain the required number of credits will be qualified for the Certificate of General Education. This certificate with an excellent score allows students to transfer directly into the second stage of the undergraduate programs and to have priority in choosing their specialization. Students who gain the certificate with a low score are required to pass the transfer examination to be accepted into the second stage. Those who fail this exam, can enroll in the technical and vocational school. Students who finish their general studies before the stage deadlines may register for some courses of their majors to reduce the university training duration. Those who have not gained enough accumulative credits required in the first stage are allowed to register again for the first-stage courses. However, general education training may be extended to at most 5 terms.

For the second stage, students are provided with specialized knowledge depending on their majors. Students have to spend 5 or 7 terms at the second stage depending on the chosen majors to obtain the required number of credits to be qualified for the Bachelor Degree. They are required to complete at least 120 credits from the specified courses and correspondent elective courses.

There are two main semesters in an academic year: semester 1 (from September to January), semester 2 (from February to June), and a summer session (from July to August). Each of term 1 and 2 consists of 17 weeks (15 weeks for teaching and learning, 2 weeks for final examinations), the summer session lasts only 8 weeks (7 - 1). Students are permitted to register at least 8 courses (30 credits) for each semester or 4 courses (15 credits) for the summer session. Last summer session is the first summer session at this college. The college only offered the core and elective courses that had been offered in the two previous terms and some new elective courses for each program (no new core courses were offered in the last summer session). The purpose of this decision is to help some students who failed in some courses have a chance to obtain the number of required credits. Those who gained the required credits can register in further elective courses to reduce their training duration. Therefore, all students who registered core courses in last summer session (such as Physics A1, physics A2, and so on) include those who failed core courses in the two previous terms.

Students who served as participants in this study finished their first two semesters at the CGS and enrolled in the summer session. They registered in courses of program 1

(Physics A1 including mechanics, molecular physics, and thermodynamics is one of the core courses in the first term, Physics A2 including electricity and magnetism is one of core courses in second semester) and they enrolled in Physics A2 in the summer session. This means that they failed in Physics A1 or Physics A2 at least once in the two previous terms. As a result, the quality of students in the summer session is rather poor in comparison with that in the two main semesters. The following data in the table 1 illustrates this:

Table 1: Student classification after the first two semesters of the academic year 1995-1996 at the CGS.

	For students participating in this study *	For total of students in the CGS **
Excellent	0%	0%
Good	0%	1.03%
Fairly good	0.7%	4.04%
Near average	13.3%	29.89%
Average	58%	46.71%
Poor	21%	13.53%
Very poor	7%	4.80%

* Obtaining on the basis of the CGPA of students who participated in this study.

** Obtaining from the Rector's report on the basis of the CGPA of students in the whole College.

This research was conducted for a large-enrollment class of about 120 full-time first-year students during two months in the summer session of 1996 in the College of General Studies (CGS), Vietnam National University - Ho Chi Minh City (VNU-HCM City). The class consists of 127 students with 126 males and only one female, aged from 20 to 25. Males are the class majority because the class includes students who would like to specialize in engineering (electrical engineering, electronics, and mechanical engineering). As indicated above, average and poor students were the majority of the class (79%). Students who entered this class had completed physics A1 course as a prerequisite for physics A2 course. These students came from various cities and provinces in the country.

Current physics course structure and teaching strategies at the CGS.

The physics A2 course on electromagnetism is one of the core lecture courses for students who major in engineering. It involves three credits. This course is taught separately from the physics A2 lab course. Because of the lack of necessary apparatus and equipment, there is no correspondence between the two courses. This means that the lecture and lab courses involve different topics. There are very few common topics in these courses. The reason is that the college has been utilizing the lab facilities that were designed for a vocational school. Therefore, the lab course is not useful in illustrating and verifying some physics laws taught in the lecture course. Similarly, the lecture course can not provide adequately basic theories for students' lab work.

The content of the course was suggested by the Ministry of Education and Training based on reviewing the course content from the Western and Eastern science textbooks. The material covered in the course includes 7 chapters, providing basic knowledge related to electromagnetic phenomena. This course has been taught with the lecture method on the basis of the two main teaching materials. The first one is the textbook (General Physics for engineering students) published by the Ministry of Education and Training. The content of this textbook was not being presented as a coherent, integrated, and conceptual whole but rather as unconnected fragments. The way the content was presented failed to reveal the relationship between concepts in successive chapters. The second teaching resource is the material on electromagnetism for physics A2 course that was written by one faculty member and was approved by the Department of Physics to be used as a supplement for the textbook. This material had to some extent overcome the above weakness but it tended to emphasize heavily the use of mathematical concepts in studying physics and required students to be good at math. Therefore, some chapters of this material were presented in deductive way rather than in an inductive, experiential way in which the meaning of some physical principles was derived from the deduction of mathematical formulas. This better serves a few top students because it was written at a highly abstract level. Both of these materials failed to adequately develop the understanding of physical concepts and physical meaning of principles. Technological applications were also introduced in both of these materials at the end of some chapters but the presentation was descriptive, failing to make students aware of the practical meaning of physical laws. Moreover, the current physics teaching at the CGS has tended to underplay the role of technological applications and their relations to knowledge of physics. As a result, stimulating students in studying physics is very difficult.

The teaching format is mainly students' taking notes from the lectures given by the instructor. The schedule for the two main terms is usually three or four 45-minute periods per week. But in the summer session, the schedule is usually six 45-minute periods per week. Students had to attend class about 30 or 35 hours per week. Thus, the time for self-studying was limited. Students were not able to think about the lessons in adequate depth. They had little time to read supplementary materials besides the textbooks and their notes taken in class. There were very few textbooks and supplementary materials relating to the course in the library and most of them were out-dated. The instruction was mainly the passive transmission of information from the textbooks to students by the instructor. Form of instruction does little to help students develop their critical thinking skills and creative abilities. Teachers do not require students anything besides the memorization of the lectures and knowing how to solve some basic physics problems to prepare for the final examination. Student assessment focuses mainly on the final exam that evaluates how well students memorize the course content and solve physics problems. The teachers have never done class demonstrations to encourage students in their studies because of many reasons, such as inadequate budget, lack of equipment for physics demonstrations, or too much effort required when setting up demonstrations. But the main reason is that most teachers have not still seen enough value in lecture demonstrations. Apparatus and equipment supported by the US before 1975 have been set aside for more than two decades.

Instructional design

The purpose of this study was to design some topics on electromagnetism in which the physics lectures were combined with demonstrations by using the learning cycle. The intended objectives of this design were to provide opportunities for students to:

- Comprehend concepts, principles or laws of physics.
- Gain understanding of technological applications based on physics laws.
- Acquire skills of observations, logical analyses, and scientific reasoning.
- Develop positive attitude toward studying physics.

A detail design of this curricular model was presented in Chapter 4. The design was tested in a first-year class at the CGS to investigate students' understanding of the concepts and principles of physics, their perceptions of technological applications, their intellectual development, and their responses to the study. In this field testing, the researcher played both the roles of the instructor and the investigator. The class sessions were performed in a large room containing more than 100 students, equipped with a blackboard, some chalk. and a microphone. Demonstrations were presented in the physics laboratory for each student group of twenty each time.

As mentioned in the above section, the current science teaching could not achieve the intended objectives. This design attempted to develop and to implement relevant teaching and learning activities using lecture demonstrations and the learning cycle model for the physics A2 course at the CGS. The learning cycle was utilized in this design not only as a method of teaching but also a method of organizing curriculum materials. The learning cycle with its three phases involves student's evaluations and discussions. It was designed so that the researcher could elicit students' background before the lecture and could get information about students' acquisition of knowledge after the lecture for every topic. As indicated in chapter 2, the learning cycle has usually been used effectively for small classes of about 30 students. However, in the CGS, teachers are often required to teach physics courses for large-enrollment classes including from 100 to 200 students. To adapt the learning cycles for a big class, it is necessary to combine students' activities implemented in the physics laboratory and large-class sessions. The format of this instructional design is outlined below:

Each learning cycle began with the student's exploration activities in the physics laboratory during a hour a week (on Monday every week). Each exploration phase included a number of demonstration experiments called activities. The equipment for each activity is available in the physics laboratory. The class was divided into six groups of 21 or 22 students. Three groups worked on Monday morning in the lab in separate sessions (from 7.00 to 8.00 for group 1, from 8.00 to 9.00 for group 2, and from 9.00 to 10.00 for group 3). The other three groups worked on Tuesday morning. At first, the teacher presented demonstrations for students, after that each of them could repeat or do some more demonstrations to get more information in order to identify the concepts, laws of physics, or to explain physical phenomena. These exploratory activities require a large amount of student-teacher and student-student interaction. However, because of the shortage of some teaching assistants, most of the exploration activities were performed by students working together in a small group of four or five divided spontaneously. Therefore, the teacher was present all the time in the physics laboratory to assist students if necessary. These activities required students to explore a concept or a law of physics through demonstrations. After observing and discussing with their peers, they were asked to answer all the questions raised in written form on the printed material on physics demonstrations (Laboratory manual for physics demonstrations). Students were asked to leave the completed activity sheets in the physics laboratory. These sheets would provide the researcher with information about students' background of the physical concepts and principles before the lectures. They would also be used for student evaluation.

The concepts and principles that had been explored were introduced through lecture discussion format in the class sessions after a few days (on Wednesday) so that students had time to think about them more deeply at home. These lecture discussions could be held in a class of 120 students because students had all had the same experiences before the class sessions. The exploration phase, together with the activity sheets, promoted students to actively participate in the discussions in a large class. After the introduction of the new concepts or principles, other learning activities were performed such as deriving some mathematical formulas to show students the relation between experiments and theories.

Each learning cycle ended with the students' application activities lasting an hour in the physics laboratory on Friday (for three groups), and on Saturday (for the other three groups). Students were asked to do some more demonstrations involving the same concepts or laws of physics, especially demonstrations relating to technological applications. This phase involved students' predictions for new situations based on the knowledge received in the large class. Their predictions would be tested experimentally in the physics laboratory. As in the exploration phase, they were also asked to answer all the required questions on the activity sheets and leave their completed activity sheets in the physics laboratory for student evaluation. These sheets would provide the researcher with information about students' understanding of the physical concepts and principles immediately after the lectures.

Students started the exploration of the next cycle in the next lab session. The next class session is utilized for answering further questions, summarizing the previous week's activities, and began the second phase of the next cycle.

During the process of pilot teaching, the Van De Graaff generator could not function properly. Therefore, some electrostatic demonstrations could not be performed as intended. These demonstrations were presented to the students in oral form by the teacher. The data in the exploration and application phases were collected by the students through the teacher's descriptions instead of from "live" demonstrations. This situation might not influence the data collection and analysis because data analysis would be implemented in separate manner for every topic. The researcher did not intend to compare students' acquisition of knowledge between different topics. Furthermore, the research on the importance of the form of student acquisition of data in physics learning cycle indicated that:

> ...there are no significant differences resulting from the various form of receiving data which these students experienced. Collecting their own data, being given it in a written form, receiving it orally, collecting it through watching a videotaped demonstration or through watching a "live" teacher demonstration did not affect the content achievement of the students as measured by the CATs. (Renner, Abraham & Birnie, 1985, p. 315).

For student evaluation, grades were assigned to each exploration and application phases. The exploration phase was graded on a Satisfactory or Unsatisfactory basis. To obtain a Satisfactory, each student had to answer each question on the activity sheet. Each Satisfactory was translated into five points when course grades were calculated. No points were given for an Unsatisfactory. The application phase was graded on a scale of 0 to 10. In this phase, grades were based on the student's abilities to use concepts and laws of physics presented in the class sessions in explaining physical phenomena. A student's course grade was computed by using the following components:

Exploration phase	10%
Application phase	20%
Midterm test 1	15%

- Midterm test 2 15%
- Final examination 40%

All students were informed of this scheme at the beginning of the class.

Instruments used in collecting data

Activity sheets

During the process of applying the learning cycle to combine the physics lectures with demonstrations, students were asked to answer a number of questions for every topic that was designed in chapter 4 on their activities sheets for both the exploration and application phases. These questions were mainly focused on requiring students to explore new concepts, principles of physics, or to explain new phenomena. The students' answer to these questions enabled the researcher to gain information about the extent to which students understand the concepts and principles of physics as well as technological applications before and after every physics lecture. This way of collecting the data allowed students to feel free to express their ideas and hence the researcher was able to grasp relatively accurately students' current understanding. These activities sheets provided data for answering research questions 1 and 2 (How students understand concepts and principles of physics throught 3 phases of the learning cycle, and students' perceptions of the relationship between fundamental principles of physics and tecnological applications).

Teacher's journal keeping

The teacher kept journals after each phase of the learning cycle for each topic. The teacher's journal keeping focused on lab and class observations. It was used as an essential instrument to discover what was seen and heard in the lab and class settings, and how students behaved while doing demonstrations in the lab and during class discussions. These observations were conducted during every lab and class session. In terms of qualitative research, the researcher played the role of participant-as-observer. The lab and class observations were aimed at gaining information about students' acquisition of knowledge, students' getting involved in learning activities, how effectively each topic with learning cycles and demonstrations enhances students' intellectual skills and their motivation to study physics. With this kind of data collection, the researcher was able to follow the evolution of students' understanding through three phases of the learning cycle. The teacher's journals provided necessary data to answer research question 3 (Affective aspect of students' attitudes toward studying physics). It also contributed a substantial part to answering research questions 1 and 2. Teacher's journal keeping guide is presented in Appendix H .

Student's journal keeping

At the beginning of the class, about 10% of the students (12 students) were asked to volunteer for keeping journals after each phase of the learning cycle in every topic. They were told why they had been asked to keep journals. They were given a list of instructions about how to keep journals (see Appendix G). They were also informed of what types of issues the researcher was interested in, such as their background in math and physics, what and how they understood the topic, what activities they enjoyed, what activities they thought were effective for their learning, how much time they spent on every activity, and so forth. They were asked to describe what they learned and to discuss things that they found to be easy or difficult to understand. These descriptions would help the researcher to gain insight into the depth of students' understanding. These journals also enabled the researcher to follow some students' thoughts about their experience of learning physics. It would provide students with an opportunity for free-form commentary. The students were ensured that their comments would not anyway influence their progress in the course. Students were paid for their journal keeping.

Questionnaires

In order to get information about students' feelings and ideas toward studying physics with demonstrations, and the value of physics in their future career, students were asked to complete a questionnaire at the end of the course (see appendix F). The questionnaire covered 3 dimensions: enjoyment in physics (8 items), motivation in physics (6 items), and value in physics in student's future career and life (6 items). The questionnaire was developed based on the overall structure of the Attitudes Toward Science Inventory (ATSI) used in the study on Attitudes Toward Science of Non-science College Students by Gogolin and Swartz (1992). A Likert scale was used in this study to assess attitudes toward physics. It is a five-point scale including "strongly disagree (SD), disagree (D), undecided (U), agree (A), strongly agree (SA)". Both positive and negative items were included in each dimension. Items were not scored because the data from the questionnaire were analyzed qualitatively.

While students' journal keeping provided me with a dynamic picture of the evolution of the course through the viewpoints of a small number of students, the questionnaire would provide me with a snapshot picture of the state of the course at a single point. These would tell me about the attitudes and responses of non-journal keepers. The use of the questionnaire was to check the validity of conclusions drawn from data based on activity sheets, and expressed in teacher's and student's journal.

Data analysis procedure

In this study, data from different sources were analyzed qualitatively through logico-inductive analysis and the research results were expressed as verbal statements.

To answer the research question 1, the data from the first three instruments were categorized into subtopics in which each subtopic represented a concept or principle of physics. In every subtopic, the evolution of students' understanding of a physical concept or principle would be described in detail through three phases of the learning cycle. Then, the above descriptions would be analyzed and interpreted. Finally, a synthesis and a common evaluation would be implemented.

The analysis focusing to the second research question was conducted in a similar way for subtopics involving technological applications. The answer to the third question involved two main subtopics. First, students' intellectual development would be described and analyzed from the first three instruments (activity sheets, teacher's and students' journals) on the basis of the synthesis of relevant chosen data. Second, students' attitude toward studying physics would be examined on the basis of the questionnaire and relevant parts of the data from the teacher's and student's journals.

Chapter IV

Instructional design

This chapter is devoted to designing a curricular model using the learning cycle to incorporate demonstrations into lectures for physics instruction at the first two years of university level. This design is reserved for science students especially for engineering students. The design was based on a modified version of Tyler's logical-rational approach to curriculum development advocated by several prominent curriculum theorists such as Taba, Mager, Popham, Doll, Saylor, and Alexander. This approach includes the following basic components:

- The statement of rationale for instructional design.
- The purpose of the intended curriculum, the goals it should achieve, and the needs it would meet.
- The formulation of the instructional design including the determination of the intended objectives, the selection of an appropriate instructional design, and relevant teaching strategies.

Rationale

Knowledge of physics in general or that of electromagnetic phenomena in particular is very necessary in the present society. It has been the foundation of advances in science and technology. It supplies learners with a basis for a better understanding of the nature and the world they are living in. Studying physics will give students a feeling of the beauty and philosophical value of the subject as well as the scientific way of thinking. There has been abundance of applications of electromagnetic phenomena to technology and real life. Students who major in science, especially in engineering should be provided with such knowledge. They should be motivated by illustrating the basic electromagnetic laws with engineering applications. With demonstration experiments incorporated into the physics lectures, student will have opportunities to see practical demonstrations of the theoretical principles. All of these are crucial to any science or engineering student. Through studying physics with demonstrations, students will be provided with good opportunities to develop their creative and critical thinking abilities, and scientific reasoning skills.

Purpose, goals, and needs

Purpose

There are many different opinions on the purposes of science education. The educational purposes that were offered by Goodlad (1984) include four missions:

- An academic-intellectual mission.
- A personal development mission.
- A social development mission.
- A vocational preparation mission.

These missions have been part of educational thought for decades. However, educational practice usually emphasizes the academic-intellectual mission. This instructional design seeks to address this imbalance by pursuing goals that reflect all four purposes of education. The academic-intellectual mission is the dominant purpose of current science education in Vietnam. In this study, the researcher attempts to improve this situation by designing a curricular model so that the four purposes of education are relatively equally presented in the goals of this design. The following example illustrates this kind of balance.

In the study of general physics at the CGS, students learn about electromagnetic induction. To teach this topic, the teacher usually uses the lecture method which begins by describing verbally the phenomena of electromagnetic induction, and then offering a word definition of it and its corresponding mathematical formula. The students are then required to apply this knowledge to solve word problems in the textbook. The study of this topic usually ends here and the academic-intellectual mission may have been fulfilled.

In this design, the students will be guided to explore other dimensions of this topic using the learning cycle. At first, students will be asked to do a number of basic demonstration experiments on these phenomena in the physics laboratory, and answer some questions raised by the teacher on the activities sheets. After that, in the class session, the teacher will let students discuss these questions together to arrive at an understanding of the physical concepts or principles. Finally, they will be asked to return to the physics laboratory to apply what they just learned to a new situation for further understanding. In this case, the students are provided opportunities to develop their interpersonal skills, self-confidence, creative abilities, critical thinking skills. In this way, they can develop a clear understanding of the basic science knowledge and concepts. In addition to basic demonstrations of principles and laws of physics, other demonstrations are available to be done by students to enable them to understand the application of scientific knowledge to technology as well as to their daily life. For example, the demonstration of the application of eddy currents shows students the principle of damping unwanted oscillations in sensitive mechanical balance scales used to weigh small masses or in electrical meters such as galvanometers, voltmeters, ammeters. As a result, the social, personal and academic mission should have been accomplished.

Goals

The major goal of this instructional design is the deep understanding of the basic science knowledge and concepts. Other goals, consistent with the purpose identified, are as follows:

- Science or engineering students should be provided with the opportunities to comprehend scientific knowledge in relation to technological applications in order to equip them with good background for further study and their future career.
- The design should provide students with opportunities to develop their interpersonal skills, self confidence, creative and critical thinking abilities, and scientific reasoning skills.
- Students with high ability or special interest in science should be challenged and encouraged to continue their study of science.

Needs

The current science education in Vietnam fails to meet some basic needs. The first one is that after completing the first phase, students must have a thorough understanding of basic science knowledge. However, as indicated in the introduction, students' current understanding of science concepts is very low. Because of the lack of supportive approaches besides the lecture method, it is easy for students just to take notes and let the lectures go from ear to ear without really absorbing anything. The second need is that science and engineering students leave the CGS with a holistic view of the principles of science, and with a certain degree of the understanding of simple technological applications. As shown in chapter 3, the textbooks and the current physics teaching at CGS fails to lead students in developing an understanding of the physics underlying everyday life and especially its technology aspects.

The ultimate purpose of basic science education is not only imparting students "pure" science but also helping them make sense of how science is applied to technology. Science study has more meaning when it is applied to real life. Therefore, in addition to basic demonstrations of principles and laws of physics, this design seeks to offer as many demonstrations relating to technology and every day life as possible. However, because of the scarcities of apparatus and equipment, this study seeks to balance between this second need and the point of being manageable, such as designing simple demonstrations that require inexpensive equipment and little time to set up.

Formulation

Objectives

This instructional design seeks to achieve the following objectives:

- Provide students with opportunities to comprehend the science concepts, principles or laws of physics through lecture demonstrations.
- Gain understanding of the relationship between fundamental principles of physics and technological applications.
- Solve mathematical and theoretical problems in the area of electricity and magnetism.
- Acquire the skills of observations, logical analysis, and scientific reasoning.

- Develop a positive attitude toward studying physics.

Selection of appropriate design and relevant teaching strategies

The next task is the selection of demonstration experiments that are appropriate to every subject content in the physics course. Accompanying this is the choice of a relevant model of instruction to effectively incorporate the lectures with the demonstrations. On the basis of reviewing the available models of instruction, the learning cycle (Karplus, 1977) was chosen because this model of instruction provides students with an active learning experience, and provides the teacher with a framework for understanding how students think and learn. Moreover, this model facilitates students' conceptual understanding as well as their comprehension of physical principles. At the university level, there is much more content to teach and learn than time allows. Therefore, time is a crucial resource in education and it also needs to be utilized appropriately.

The content of demonstration experiments was chosen on the basis of the following criteria:

- The nature of basic science knowledge itself. Science is not only a body of knowledge but it also encompasses the skills and processes by which that knowledge is created. The learning activities that will be selected for this design attempt to establish the balance between processes of science and products of science.
- The nature of relationship between science and technology. Learning activities are chosen to guide students towards an understanding of physical concepts and principles, as well as that of technological applications involved in the use of this basic science knowledge.

- The nature of the learning process itself, including two major characteristics: readiness and motivation.
    1. Readiness: The readiness of students to embark on this instructional design depends largely on their mastery of mathematics and physics at the high school level as well as advanced mathematics taught in the first semester of the first year of university. Therefore, this design should be taught at least in the second semester of the first year. A review of basic concepts and skills of calculus and vector calculus was available in every topic designed. Learning activities presented this chapter address this characteristic of facilitating students' understanding. Besides, students' answers to the questions in the exploration phase was used as diagnostic test of their knowledge of high-school physics.
    2. Motivation: This design seeks to provide students with learning activities and experiences to motivate them intrinsically to study science. The selection and organization of the content of demonstration experiments seeks to make students see intrinsic value in the content as well as the processes of the design.
- The availability of appropriate equipment and resources (showing in every topic in the instructional design), and teaching materials (see appendix C).
- Available time for students working with demonstrations was 10 hours in the total of 45 hours of the whole course (see appendix C).

As mentioned above, the learning cycle model was chosen to incorporate the lectures with demonstrations in which every topic will be taught through the following three phases:

1. *Exploration phase*: This first phase requires students to explore a concept or a law of physics by performing a series of demonstrations. They work and discuss in small groups. They will be provided with instructions, some equipment, and some questions about the demonstration experiments involved. They are asked to explore the problems experimentally in as much detail as they can and to relate their findings to other experiences they have had.
2. *Concept introduction phase*: This phase requires students to describe and explain observations in the exploration phase. Using these observations, the teacher guides students toward expository statements of concepts and principles. This phase involves discussion in a large class because students had the same experience from the exploration phase.
3. *Concept application*: This phase requires students to use the concepts or principles that were introduced and to apply them to new situations. Students work and discuss in small groups. This phase, if successfully executed, will lead students to further understanding of the theories.

Based on the above design principles, a detailed instructional design was implemented. This design is focused on electricity and magnetism sections of physics courses including the following topics:

Topic 1 ***: Electric charge, polarization, and electrostatic induction***

Learning objectives

Students should be able to:

- Understand the concept of electric charge.
- Grasp the phenomena of polarization and electrostatic induction, and discriminate between the conductors and insulators.
- State Coulomb's law, write its mathematical formula and use it calculate the electric force exerted by one charge on the other charges.

Learning activities and demonstrations

Exploration demonstrations

Let groups of students do these experiments in the physics laboratory and then answer some questions below on the activity sheets after discussing in small group.

1. Concept of electric charge

Equipment: Two glass rods, two plastic rods, a piece of silk, a piece of fur, a string, and a ring stand.

Procedure:

a) Rub the glass rod with the piece of silk and suspend the rod from the ring stand by the string so that it is free to rotate. Next, approach this rod with the second rod that has also been rubbed with silk, students will find that the rods repel each other.

b) Do the same experiment with two plastic rods rubbed with fur.

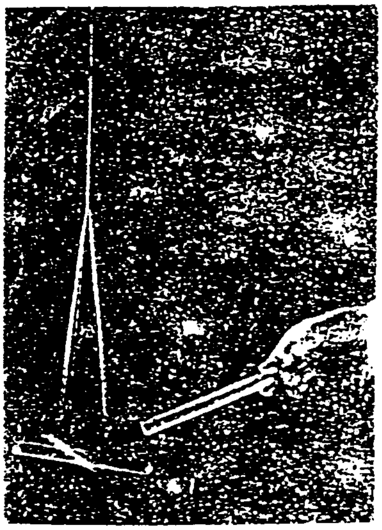


Figure 2: Electrostatic interaction

c)Approach the plastic rod that has been rubbed with fur with the glass rod that has been rubbed with silk, students can find that the rods attract each other.

d) Approach the glass rod rubbed with silk with some small pieces of paper. Students can see that the glass rod attracts them.

e) Do the same experiment with the plastic rod rubbed with fur.

Questions:

- Why do the two glass rods rubbed with silk or the two plastic rods rubbed with fur repel each other?
- Why do the glass rod rubbed with silk and the plastic rod rubbed with fur attract each other?
- Why do both the glass rod rubbed with silk and the plastic rod rubbed with fur attract small pieces of paper?

These demonstration experiments provide students with experimental observations through which they can understand the concept of electric charge, the concept of polarization, and charging by rubbing, the existence of two kinds of charge: positive and negative, and the interaction between them.

2. Electrostatic induction:

Equipment: An electrophorus (consists of a thick plastic base with rubber feet and a round aluminum plate with an insulating handle), a piece of fur, and an electroscope.

Procedure:

a) Rub the plastic base with fur (it will be charged negatively). Then place the metal plate on the plastic base and ground the metal plate by touching it with the student's knuckle. Students can hear a small spark (the plate is now positively charged).

b) Remove the metal plate by holding the insulating handle and touch it with the electroscope. Students can see the two aluminum leaves of the electroscope repel each other.

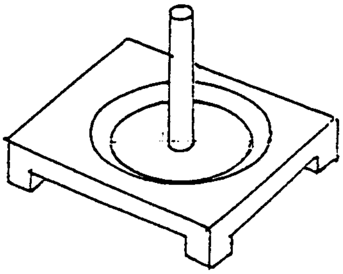


Figure 3: Electrophorus

Questions:

- What happens when the plastic base is rubbed with fur?
- Why can a small spark be heard when you touch the metal plate with your knuckle?
- Why do the leaves of the electroscope repel each other when you touch the metal plate with the electroscope ?

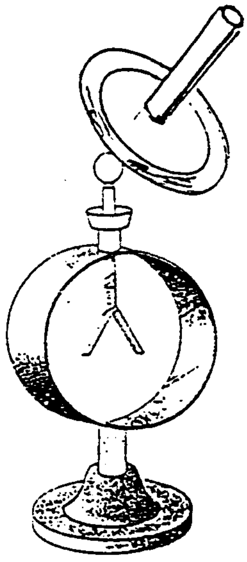


Figure 4: Electroscope

This demonstration helps students to visualize electrostatic induction and to grasp how to charge by induction, from which they can discriminate the difference between charging by rubbing and charging by induction. Based on this experiment, students can recognize the difference between insulators and conductors. This will stimulate them to seek to understand the structure of matter.

Concept introduction and other learning activities

- Let students discuss what they observed during the exploration phase to lead them to the concept of electric charge, polarization, charging by rubbing, charging by induction, two kinds of charges, and the interaction between them.
- Describe Coulomb's experiment (It is better if we have Coulomb's torsion balance to show students this experiment, but regrettably, we can not afford it) and its conditions such as the charges considered to be point charges and placed in air, and then state Coulomb's law.
- Derive the mathematical formula for Coulomb's law.
- Let students do some problems in the physics textbook to enhance their mathematical skills.

Application demonstrations

Let groups of students do these experiments and answer the questions below on the activity sheets to check their understanding of the concepts.

1. Equipment: A long piece of wood (2*4) well dried, a watch glass, an aluminum pop can, a chargeable rod, and an appropriate cloth.

Procedure:

a) Balance the long piece of wood on the watch glass so that the wood can rotate easily. Charge the rod and hold it parallel to the wood near one end (the wood will rotate towards the rod). Move the rod away from the wood (the wood will follow). Hold the rod on the other side (the wood will stop and rotate in the opposite direction). In some cases, students can recognize that the rod attracts the wood.

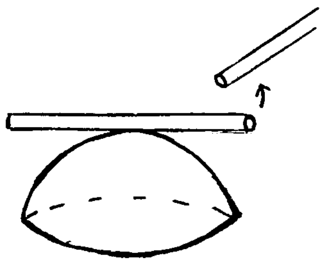


Figure 5: Piece of wood on the watch glass, and charged rod

b) Repeat the same experiment with the pop can, check that the pop can is absolutely round (this means that it has not been flattened slightly on any side).

Questions:

- Why does the wood follow the charged rod when you move the rod away from the wood? (or why does the rod attract the wood? if students recognize the attraction between them).
- Answer the same questions for the experiment b.

2. Equipment: A glass rod, a piece of silk, two metal balls attached separately to two insulating bases, two strings, and two ring stands.

Procedure:

a) Charge the glass rod by rubbing it with the piece of silk and bring it near two uncharged metal balls in contact. Separate the balls and then remove the rod away from them.

b) Hang the balls from two separate ring stands by two strings, avoid not to touch them, and bring the rod near each of them in succession to check the sign of the electric charge on them.

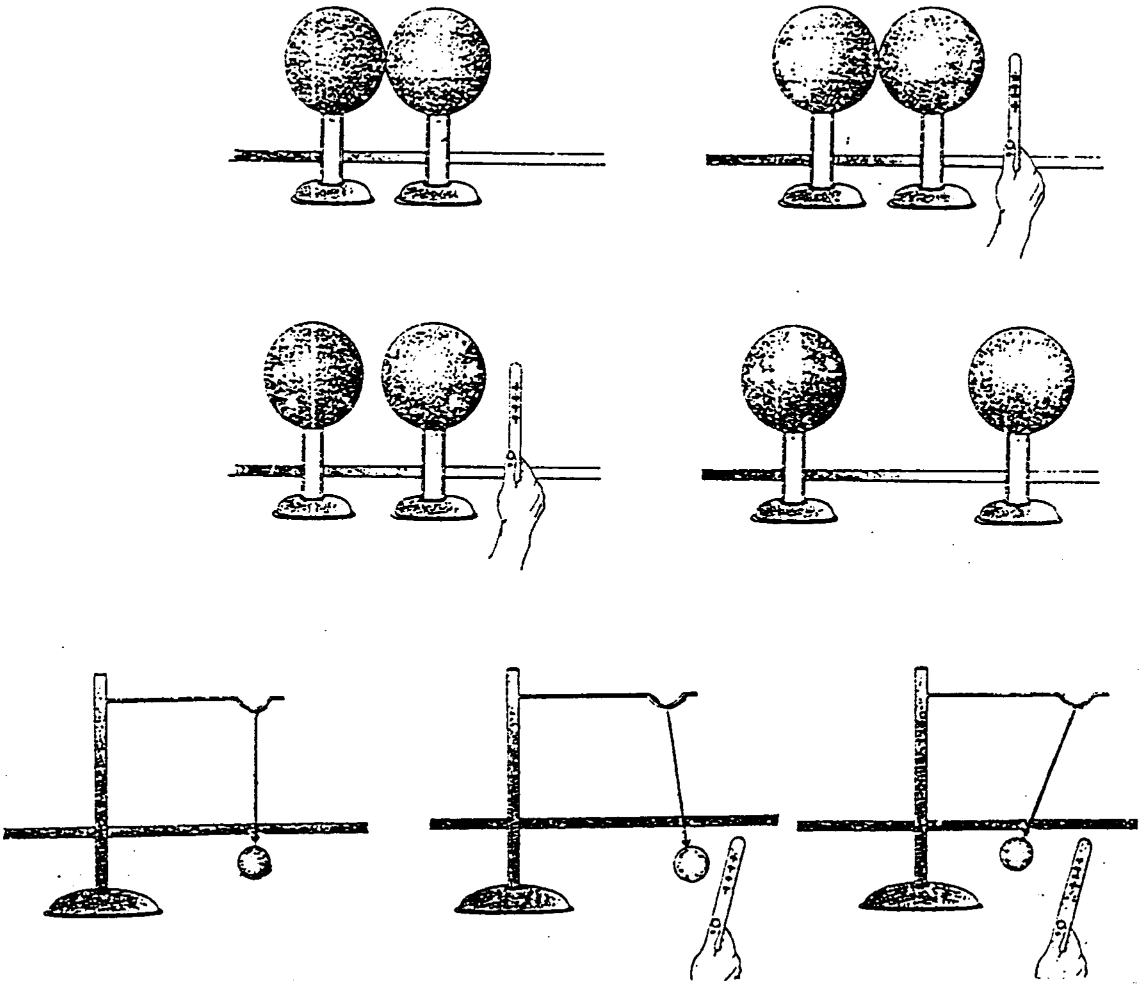


Figure 6: Charging by induction

Questions:

- Explain why the glass rod attracts one ball and repels the other one.
- Describe how to charge a single metal ball by electrostatic induction.

3. Equipment: a glass rod, a plastic rod, a piece of silk, a piece of fur, a metal ball, a string, and a ring stand.

Procedure:

a) Hang the metal ball from the ring stand by the string and charge the glass rod by rubbing it with the piece of silk. Bring the charged glass rod near the ball (the ball will be attracted).

b) Stick the rod to the ball for a while (the ball will be repelled).

c) Charge the plastic rod by rubbing it with a piece of fur and bring it near the ball (the ball will be attracted).

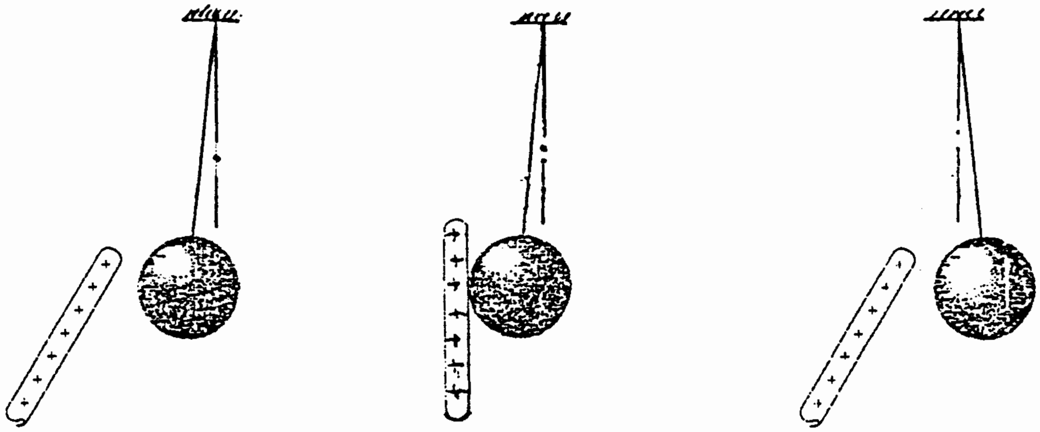


Figure 7: Electrostatic induction

Questions:

- Explain the attraction between the ball and the glass rod in the experiment a.
- Why is the ball repelled after being stuck to the rod for a while?
- Explain the attraction between the ball and the plastic rod in the experiment c.

Topic 2 : Electric potential

Learning objectives

Students should be able to:

- Understanding the concept and define the term electric potential.
- Write the mathematical formulas for electric potentials due to a single point charge, a distribution of point charges, and continuous charge distributions.
- Comprehend the relationships between electric potential and electric field as well as electrostatic energy.
- Understand the concept of equipotential surfaces and their properties.

Learning activities and demonstrations

Exploration demonstrations

Let students do these experiments and answer the following questions on the activity sheets.

<u>Equipment</u>: An electrophorus, and a charge detector.

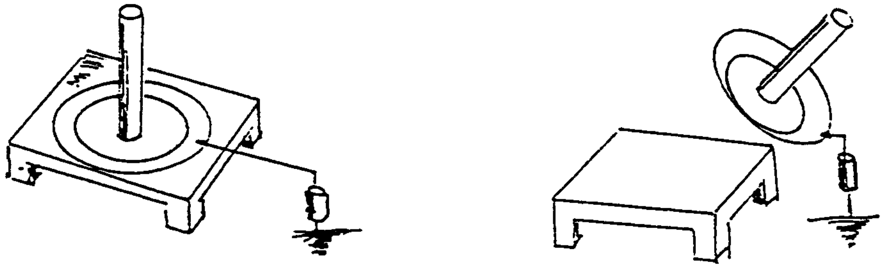


Figure 8: Electrophorus and charge detector

<u>Procedure</u>:

a) Rub the plastic base with fur. Place the metal plate on the plastic base, and then ground it through a charge detector (students can see a flash from the charge detector).

b) After grounding, disconnect the metal plate from the ground, and lift the metal plate away from the base by holding the insulating handle (ensure that the plate is still in the electric field of the base). Connect the metal plate again to the ground through a charge detector (students can see a brighter flash from the charge detector).

Questions:

- Is the plastic base charged positively or negatively after being rubbed with fur?
- Why does the charge detector flash when the metal plate is grounded through it?
- Are the charges on the metal plate positive or negative after it is grounded in both experiments a and b?
- Why is the flash brighter when the metal plate is pulled away from the base and grounded again?

This experiment recalls students to charging by rubbing as well as by induction. Simultaneously, it shows that grounding the electrophorus plate through a charge detector will produce a flash when the charges flow to the ground because there is a potential difference between the plate and the ground. I hope that students would use the concept of electric potential that they learned in high school to interpret what they observed. Otherwise, the teacher should give more questions to guide them. When using this concept, students maybe recognize that the metal plate will have a charge opposite that of the charge on the plastic base. Through this experiment, the teacher should make students realize that when the metal plate is lifted away from the plastic base, work has been done on the charges. This work results in giving the charges a higher potential relative to the ground. Therefore, when the metal plate is grounded in the separate position, the charges are transferred at a high potential and more energy will be released producing the brighter flash of the charge detector. This process will make students grasp the meaning of the potential that is the work done by the electric field through using the scientific reasoning instead of memorizing.

The purpose of this demonstration is to clarify the meaning of electric potential. It helps students more clearly understand the concept of electric potential, which is a difficult point in the physics curriculum.

Concept introduction and other learning activities

- Let students discuss what they discovered from the exploration demonstrations to lead them to the concept of electric potential.
- Define potential difference based on the conservative property of the electric force and write the mathematical formula for it.
- Define the electric potential function, derive its mathematical formulas, and show students how to calculate the potential from a given charge distribution or from a given field.
- Derive the relationship between the electric potential and the electrostatic potential energy.
- Recall the mathematical concepts such as directional derivatives and gradient vector and apply these concepts to derive the formula showing the relationship between the electric field and the potential.
- Define the term equipotential surface and infer their properties from the Gauss's law and the formula for the relationship between the potential and the electric field.
- Do some problems in the textbook to enhance the mathematical skills.

Application demonstrations

Equipment: a charge object, a metal ball, and a charge detector.

Procedure:

a) Place the metal ball near the charged object. Then ground it through the charge detector. It flashes when grounded.

b) Disconnect the metal ball from the ground. Move the metal ball far away from the charged object, and then connect the ball to the ground through the charge detector. A brighter flash can be seen.

Question:

- Why is the flash brighter when the metal ball is at the position far away from the charged object?

Topic 3 : Conductors in electrostatic equilibrium

Learning objectives

Students can be able to

1. Grasp the properties of conductors in electrostatic equilibrium:
   - There is no electric field inside a conductor in an external electric field.
   - Electric charges on a conductor only exist on its surface.
   - Electric potential is constant everywhere inside a conductor in an electrostatic field.
   - Electric-field lines are perpendicular to the conductor surface.
2. Understand some technological applications based on these properties of conductors.
   - The principle of "shielding" electrical equipment by placing it in a metal can.
   - The principle of operations of the Van de Graaff generator.

Learning activities and demonstrations

Exploration demonstrations

Let groups of students do these experiments and answer the questions below on the activity sheets.

Equipment: A metal hollow globe, a small spherical conductor, a Van de Graaff generator, a test charge, and a conducting wire.

Procedure:

a) Place the uncharged hollow globe in the external field of the Van de Graaff generator. Use the test charge to check the existence of the electric field inside and outside the hollow globe. Hang the small uncharged conductor inside the hollow globe but not touching it and check again.

b) Place the small charged conductor inside the hollow globe but not touching it. Check the electric field inside and outside the globe by using the test charge.

c) Connect the globe and the small conductor with the conducting wire and check again.

d) Disconnect the globe and the small conductor then use the electroscope to show that there is no charge on the small conductor in this case.

e) Recharge the small conductor with the same sign and connect it with the globe. Use the electroscope to check whether or not it is charged. Repeat this experiment many times and ask students to arrive at a conclusion relating to the operation of the Van de Graaff generator.

<u>Questions</u>:

- Explain why there is no electric field inside the hollow globe in experiment a.
- Explain why there is an electric field inside the hollow globe in experiment b.
- What conclusions can be inferred from experiments a and b?

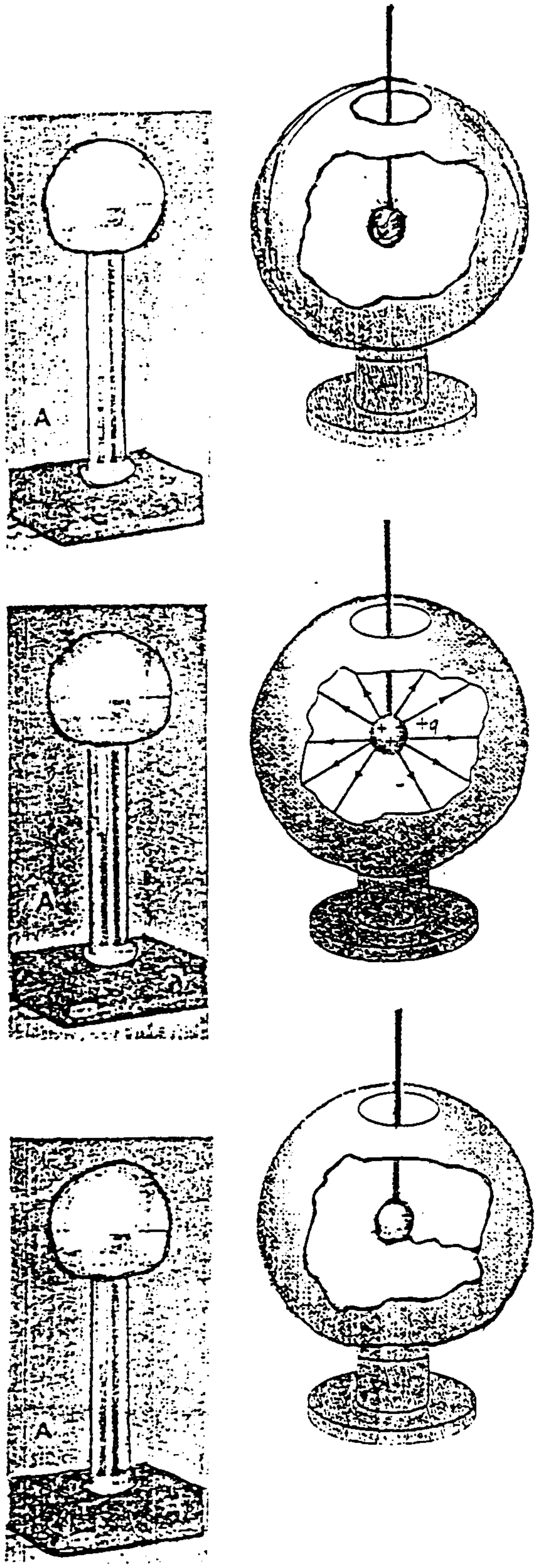


Figure 9: Van De Graaff generator, metal hollow globe, and metal sphere

- Explain why there is no electric field inside the hollow globe when it is connected with the small charged conductor placed in it in experiment c.
- Explain why there is no electric charge on the small conductor after you connect it with the globe.
- Do you think that the results of these experiments can be applied into technology? Can you explain in details those technological applications?

These demonstrations make students grasp the first two properties of conductors in electrostatic equilibrium. Demonstrations a, b, c, and d imply that a cavity is completely enclosed by a conductor, no static distribution of charges outside can produce any electrostatic fields inside. This explains the principle of "shielding" electrical equipment by placing it in a metal can, that has been used in technology. On the other hand, the distribution of charges inside a closed conductor can produce electric fields outside. This means that "shielding" works only one way. Demonstration e relates to the method used to produce large potentials in the Van de Graaff generator in which the charges are brought to the inner surface of a large spherical conductor by a continuous charged belt.

The above demonstrations reflecting both physics-oriented and technological-oriented aspects will positively contribute to achieving the purposes of science education.

Concept introduction and other learning activities

- Let students discuss the exploration demonstrations to lead them to the introduction of the first two properties of the conductors as well as their technological applications.
- Use the mathematical expression learned in the previous topic involving the relationship between the electric field and the electric potential to derive the third property of conductors in electrostatic equilibrium.
- Use the third property and the above expression when applying to a small displacement dl on the conductor surface to derive the fourth property.
- Use Gauss's law to check the second property so as to show the appropriateness between theory and experiment.

Application demonstration

Let groups of students do these experiments and answer the following questions to know how they understand the lesson.

Equipment: A metal hollow globe, a small spherical conductor, and a test charge.

Procedure:

a) Place the small spherical conductor carrying a positive charge inside the hollow globe but not touching it. Use the test charge to check the existence of the electric field inside and outside the globe.

b) Connect the globe and the small conductor with a fine conducting wire. Check again the existence of the field inside and outside the globe. Use the electroscope to check the charges on the small conductor.

c) Place the small uncharged conductor inside the charged hollow globe but not touching it and then ground it through the charge detector. Disconnect the small conductor from the ground and use the electroscope to check the charges on it.

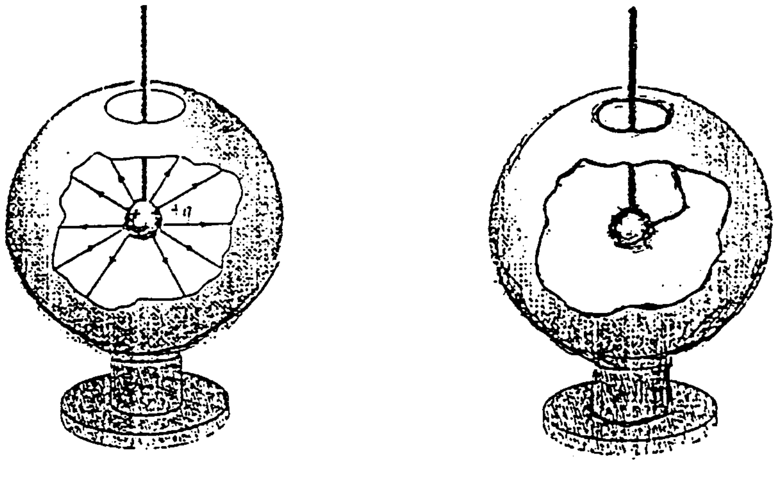


Figure 10: Metal hollow globe and metal sphere

Questions:

- What conclusions can be inferred from experiments a and b?
- Show the difference between the experiments a and b, and those of exploration demonstrations involved in this topic.
- Why does the charge detector flash when the small uncharged conductor is grounded through it in experiment c?
- Why is the small conductor charged in experiment c? Can you guess the sign of the charges on it?

***Topic 4* : Electromagnetic induction**

Learning objectives

Students can be able to:

- Interpret Faraday's experiment on magnetic induction phenomenon.
- State Faraday's law and use it to find the induced emf by a changing magnetic flux.
- State Lenz's law and use it to find the direction of the induced current in various applications of Faraday's law.
- Understand motional emf.
- Know how simple AC generators and motors work.

Learning activities and demonstrations

Exploration demonstrations

Equipment: An air-core solenoid, a loop, a strong bar magnet, a galvanometer, a model of a generator, and a model of a motor.

Procedure:

1. Connect the ends of the air-core solenoid to the galvanometer:

   a) Move the magnet toward or away from the solenoid.

b) Move the solenoid toward or away from the magnet.

c) Move the magnet toward or away from the solenoid with a faster speed.

d) Suddenly stop the motion of the magnet with respect to the solenoid.

2. Connect the loop with the galvanometer, place the magnet near it and change the area of the surface bounded by the loop by changing the shape of the loop.

3. Observe and describe the operations of a generator and a motor.

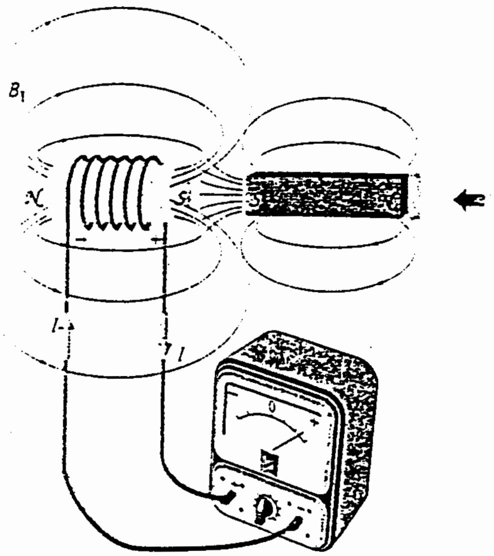


Figure 11: Magnet, solenoid, and galvanometer

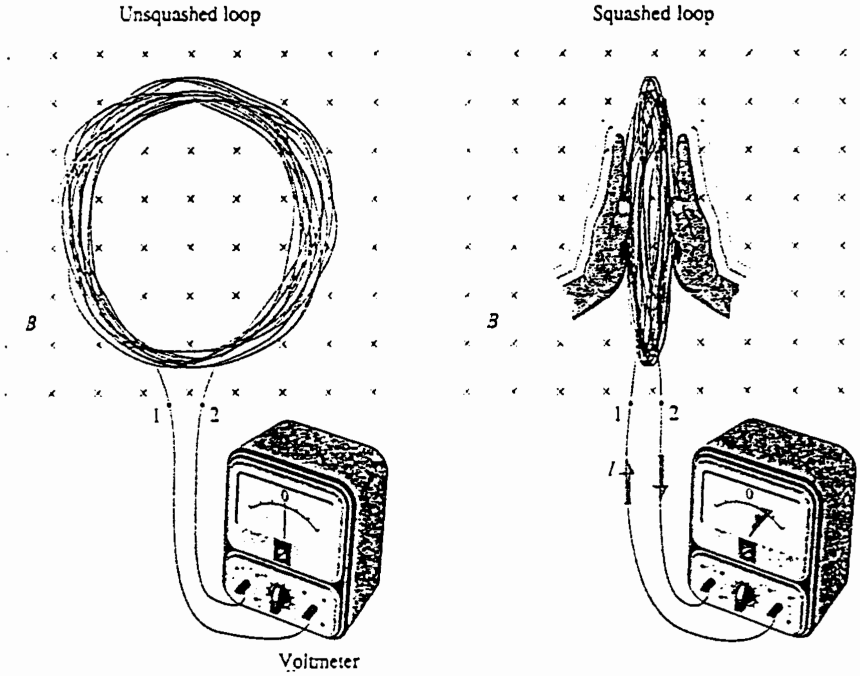


Figure 12: Magnet, loop, and galvanometer

Questions:

- What is the reason for the appearance of the induced currents?
- On which factors do the magnitude and the direction of the induced currents depend?

Other learning activities

- Let students discuss what they observed from the exploration demonstrations to lead them to the introduction of the magnetic induction phenomenon and the interpretation of Faraday's experiment.
- Define induced emf, state Faraday's law, and derive its mathematical formula.
- State Lenz's law and use it to determine the direction of the induced currents in some cases.
- Investigate the motion of a conducting rod in a uniform magnetic field to calculate the motional emf (the potential difference across the rod).
- Describe a simple generator, a motor, and their operations.
- Do some problems in the textbook to enhance the understanding of the magnetic induction laws.

Application demonstrations

Equipment: A small coil with a few hundred turns of copper wire attached to a 6-W light bulb, a strong permanent magnet, a big coil of wire with iron core, and a 110VAC supply.

Procedure: Let students do these experiments:

a) Move quickly the small coil through the magnetic field of a strong permanent magnet. The light bulb will glow brightly, and the glow is related to the speed with which the coil passes through or is pulled out of the magnetic field.

b) Move the small coil in or out of the magnetic field. They will get a feeling for the opposition to the motion of the coil. If this effect cannot be clearly recognized, let students do the similar demonstration: rotate a copper disc in the air, and then in the magnetic field of a magnet. Students can easier identify that its motion in the magnetic field is slower than that in the air.

c) Use the big coil with an iron core that can be connected with a 110VAC supply to produce a variable magnetic field. Hold the small coil near the big coil which is now unplugged, then plug the big coil into 110VAC supply without moving the light bulb, the bulb will glow.

d) Investigate the effect of small coils with the different number of turns.

Figure 13: Iron-core solenoid, and coil connected to light bulb

Questions:

- Why does the bulb glow while being moved in the magnetic field of the strong permanent magnet?
- How do you interpret the opposition to the motion of the small coil?
- Explain why the bulb lights without any motion of the small coil relative to the system in experiment d.
- Explain the effect of coils with the different number turns in experiment c.

Topic 5 : Eddy current and its technological applications

Learning objectives

Students should be able to:

- Grasp in which conditions eddy currents are produced and know how to determine their direction.
- Comprehend the application of eddy currents in technology such as the principle of damping unwanted oscillation in electrical meters and sensitive mechanical balances.

- Understand the term self-inductance and mutual inductance.
- Grasp the concept of magnetic energy and its mathematical formula.

Learning activities and demonstrations

Exploration demonstrations

1. Eddy currents

<u>Equipment</u>: An iron-core solenoid, an aluminum ring and another one with a cut through it, a ring cut from aluminum foil, an aluminum cylinder, a copper sphere, beaker of water, a copper disc, a variac.

<u>Procedure</u>:

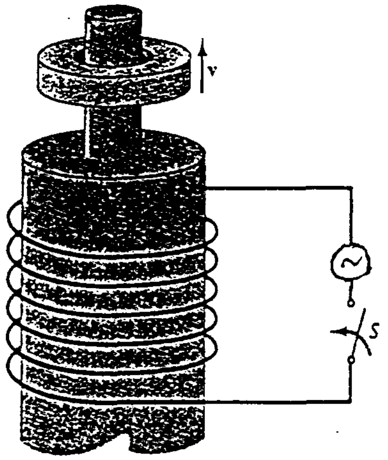


Figure 14: Iron-core solenoid and aluminum ring

a) Lift the iron core a few inches out of the solenoid, place the aluminum ring on the core and flip the switch on the variac, the ring will leap and levitate in the air, but the levitation of the ring is not stable in the direction perpendicular to the core axis. Put another aluminum ring of the same size on the core. They both leap and levitate in the air, and simultaneously they attract each other.

b) Repeat this experiment with an aluminum ring which has a cut through it, or with an aluminum cylinder, and a ring cut from aluminum foil.

c) Lift the iron core several inches out of the solenoid, fit a cylindrical copper container which holds water and support it on the post, the water will boil shortly.

d) Place the copper sphere in the beaker and add sufficient water so that the sphere just floats and it can rotate freely. Put the iron core down and then place the beaker over the core. Switch on the variac, nothing happens. Slip the copper disc under the beaker to shade part of the core, the sphere will rotate.

<u>Questions</u>:

- Why does the ring leap and levitate in the air in experiment a?
- Can you explain why its levitation is not stable in the direction perpendicular to the core in experiment a?
- Why do the two aluminum rings attract each other while leaping and levitating in the air in experiment a?
- Describe and explain experiment b.
- Why does the water boil in experiment c?
- Why does the sphere rotate in experiment d when the copper disc is slipped under the beaker?

The demonstrations a and b help students discover in which conditions eddy currents can be produced. They demonstrate the existence of eddy currents in metals and their absence in insulators as well as the dependence of the magnitude of the eddy currents on the size of the conductors. They also show the interaction between two eddy currents when two aluminum rings are placed on the core at the same time. From these demonstrations, the teacher can stimulate students' critical thinking skills by asking them to explain the fact that the levitation of the rings is not stable in the direction perpendicular to the core. Students can recognize that the rings that contain rather strong eddy currents will get hot. This remind them of the Joule heat that is illustrated more clearly in demonstration c. Experiment d inspires student's curiosity and develop their scientific reasoning ability.

2. Technological applications of eddy currents

Equipment: a strong permanent magnet, a copper disc, a slotted copper disc, a stop-watch.

Procedure:

a) Exert a definite force on the copper disc to make it rotate in the air. Use the stop-watch to measure the time it takes for the disc to rotate from the beginning to the end of the rotation. Repeat this experiment at least 5 times, and calculate the average time it took.

b) Repeat this experiment with the copper disc being made to rotate with the same force in the magnetic field of the strong permanent magnet.

c)Repeat experiment b with the slotted copper disc.

Question:

- Explain why the copper disc rotate more slowly in the magnetic field than in the air?
- Explain why the slotted copper disc rotate more quickly than the copper disc does in the magnetic field?
- Do you think the idea from these experiments can be applied to technology? Can you tell me these applications?

Concept introduction and other learning activities

- Let students discuss what they observed in the exploration demonstrations to introduce the concept of eddy current and discuss its applications.
- Define eddy currents and use Lenz's law to determine their directions in some particular cases.
- Discuss the advantages of the eddy currents such as applying eddy currents to technology to melt metals in vacuum to avoid being oxidized, to temper very thin layers of metals, and to provide braking for rapid transit cars. Remind students that sometimes eddy currents become disadvantageous because of the dissipation of Joule heating through the resistivity of metal materials and discuss how to reduce it.
- Define the terms self-inductance and mutual inductance, derive their mathematical formulas.
- Prove the existence of the magnetic energy and derive its mathematical formula.
- Do some problems in the textbook to deeply understand these above concepts.

Application demonstrations

1. Eddy currents

Equipment: An aluminum tube, an acrylic tube, a clamp with a brass hook, two identical bobs (one magnetic and one non-magnetic), a handy spring scale, a plastic cup, and a high ring stand.

Procedure:

a) Two tubes are attached together by the clamp with the brass hook mounted in the ring stand or held in the hand through the handy spring scale. The plastic cup is placed under the tubes so as a noise can be heard when the bob falls into the plastic cup.

b) Put the magnetic bob through the plastic tube and the non-magnetic bob through the aluminum one at the same time. They will emerge at the same time because there are two noises heard at the same time from the plastic cup. Remind students to be careful when dropping the bobs not to let the bobs bounce up and hit the tubes.

c) Drop the magnetic bob down the aluminum tube and the non-magnetic bob down the plastic tube at the same time. One takes several seconds longer to fall through because one noise is heard before the other one.

d) Drop the non-magnetic bob down the aluminum tube, it fall through quickly. Note the weight in the reading (the weight of the whole system below the handy spring scale).

e) Repeat experiment d with the magnetic bob, it falls through slowly. Note the weight change in the reading.

Questions:

- Interpret and analyze the experiments b and c. Why does it take longer time for the magnetic bob to fall through the aluminum tube?
- Interpret and analyze the experiments d and e. Why is there a weight change in the reading when the magnetic bob is falling through the aluminum tube? The weight increases or decreases when the magnetic bob was falling in the aluminum tube. Explain why?

2. Technological applications of eddy currents

Equipment: A strong permanent magnet, three pendulums of the same size cut from sheet of copper, aluminum, and plastic.

Procedure:

a) Make the three pendulums oscillate when there is no magnet present or when they do not pass between the two poles of the magnet. They can oscillate easily.

b) Pull the plastic pendulum and let it swing between two poles of the magnet. It continues to oscillate for a long time.

c) Pull and release the copper and aluminum pendulums at a 45° angle from the vertical and let them to swing between the two poles of the magnet. They stop within one oscillation.

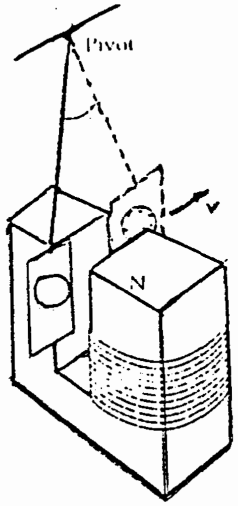


Figure 15: Magnet and metal pendulum

d) Let students look inside one of the electrical meters to see how eddy currents are applied.

Questions:

- Why are the oscillations of copper and aluminum pendulums damped more quickly than that of the plastic pendulum?
- Explain why indicating needles in electrical meters is slightly oscillated and quickly reach to mechanical equilibrium?

The purpose of this demonstration is to challenge students to think about how eddy currents are produced, how Lenz's law applies, and recall the interaction between the magnetic fields and the currents. Simultaneously, This demonstration also show students how practically eddy currents are applied to damping unwanted oscillations in technology and real life.

Chapter V

Data analyses and discussions

This chapter is devoted to data analyses and their interpretations. Major findings will be described in order to answer the three research questions raised in Chapter 1. The data analysis procedure was presented in Chapter 3. It should be noticed that the percentages presented in this chapter were computed on the basis of the total number of students attending every class or lab session. The average total was about 100 students.

Descriptions of the evolution of students' understanding

Electric charge

Most students were taught the concept of electric charge when taking physics courses at high school. But they had rare opportunities to observe phenomena that lead to the formation of this concept. In order to know the extent to which students have understood the concept of electric charge, the researcher let students do the exploration demonstration 1 of topic 1 (p. 54). Students' answers to the first two questions on the activity sheets showed that:

- 52% of students implied that after rubbing on silk, the two glass rods acquire same electric charges (like charges), and therefore, they repel each other.
- 26% of students mentioned that identical objects (such as two glass rods) that are rubbed with the same materials (such as silk) will acquire like charges, and then they repel each other. Similarly, non-identical objects (glass and plastic rods) that are

rubbed with different materials (silk and fur) will acquire unlike charges, and then they attract each other.

- 7% of students believed that friction produces transferability of charges from one object to the other, and results in charged objects.
- 5% of students supplemented that friction produces thermal energy, and then thermal energy makes the possibility of charge transferability.
- 1% of students were confused between electrostatic and magnetostatic interactions.
- 6% of students were not able to answer these questions.

In summary, 92% of students mentioned that frictional effects result in electrical interactions. 13% of them explained this in more detail with the recognition of the mobility of charges. If the concept of electric charge is understood: "as the name for the property acquired by the interacting objects - a property that seems to "leak away," can be restored by rubbing, is transferable from one object to another by contact, is highly mobile on metallic objects, and so on" (Arons, 1990, p. 146), then only 13% of students grasped this concept.

With regard to the third question (p. 55) requiring students to explain why both charged glass and plastic rods attract small pieces of paper, more than 4% of students were able to explain this phenomenon by visualizing displacement of charge within the neutral object when it is in the proximity of the charged one. They thought that opposite charges within a small piece of paper move towards the charged glass or plastic rod, and that like charges move away from it (this phenomenon is called polarization), and the net result is the attraction between the two objects. The other students (21%) thought incorrectly that charged bodies always attract uncharged ones, and regarded that as a definition. About 3% of students implied that charged bodies tend to attract uncharged ones to reach the electrical neutral state because it is stable state. The remainder (71%) gave completely intuitive and incorrect explanations. In summary, most students were not able to provide plausible explanations of the phenomenon in which one charged object attracts another uncharged one.

Dealing with exploration experiment 2, only 3% of students were able to explain the phenomenon of charging by induction. Most of them gave incorrect explanations because they were not able to visualize the mobility of electric charges (electrons) in metallic conductors.

Although students had been taught the term "electric charge" at high school, but through the exploration phase, together with phenomena and interactions leading to the formation of this concept, their understanding of this concept appeared not to be revealed clearly. Moreover, most students exposed some misconceptions related to the like and unlike charges, polarization, and electrostatic induction. Most students did not utilize the structure of matter to explain the phenomenon of polarization in non-conductors, or to explain the electrostatic induction in conductors. They were unable to discriminate between the polarization in non-conductors and the electrostatic induction in conductors without assistance from the teacher. In one sense, this is understandable, given their experience in a school system and culture in which "teachers do the explaining." The exploration phase, together with activity sheets suggested helpful topics for the next class discussion session.

In the class discussion, students revealed their understanding of the concept of electric charge with a little guidance from the teacher. The observation that two glass rods rubbed with silk always repel each other led students to the conclusion that identical objects rubbed with the same material always repel each other. This formed in students' mind a definition of "like" charge. With further thinking, some students inferred that non-identical objects rubbed with different materials acquire "unlike charges." This implausible inference was analyzed to indicate that, in this case, the two objects may acquire like or unlike charges depending on their structures of matter. The class discussion led students to the conclusion that the two objects after being rubbed with the other ones, if they repel each other, they actually acquire like charges, if they attract each other, they really acquire unlike charges. The meaning of "like" was extended to embrace all repulsive interactions and the term "unlike" was invoked to cover all attractions. The name "positive" and "negative" was then introduced respectively. The discussion also led students to the recognition of two distinct charge states.

Most students did not pay attention to the role of electric charge in the structure of matter. Therefore, they failed to give plausible descriptions of the attraction between charged and uncharged objects. During the class discussion, students were reminded of the structure of matter in explaining the polarization existing in insulators placed in proximity to the charged objects. The concept of polarization was introduced to provide a plausible account for what was observed. Students were also alerted that the phenomenon of polarization is not the cause of the attraction between charged and uncharged objects. This attraction is a kind of electrical interaction that occurs between electric charges.

With the teacher's help, some students appeared to find the process by which electrical polarization occurs not too difficult to visualize and comprehend.

Another important point was raised to discuss in the class discussion. That was the interpretation of the phenomenon of charging by induction. Many students were not able to explain this correctly in the exploration phase because they had not grasped the concept of polarization. This was made clear through the discussion that conductors with a substantial amount of free electrons become polarized in the presence of the charged object causing the induction. A distinction between polarization occurring in non-conductors and in conductors was made to lead students to discriminating between insulators and conductors. With the concept of polarization, students found the electrostatic induction not to be a difficult or mystifying process.

In the application phase, through the investigation of how students explained physical phenomena in three application demonstrations and with the implication of the concept of electric charge proposed by Arons (1990), there were 64% of students who grasped this concept. The findings indicated that there were more than 54% of students who were able to gain the understanding of the concept of polarization in terms of induced electric dipoles formed by the displacement of charges in insulators. Around 58% of students were able to correctly visualize the process of charging by induction in terms of actual displacement or separation of charges in conductors. About 36% of them had the ability to discriminate between characteristics of insulators and conductors on the basis of the understanding of structures of matter.

Teacher's and students' journals showed that through doing exploration demonstrations and attending class discussion, a large number of students have actually understood the concept of electric charge more clearly. Simultaneously, their misconceptions were detected and analyzed to lead them to a deep understanding of the lecture. Application demonstrations strengthened their understanding of physical concepts mentioned above in different instances and recommended the practical meaning of these concepts in terms of forming in the students' mind a relatively firm background to gain insight into natural phenomena.

Electric potential

The first three questions in the exploration demonstration in this topic were used as guide questions to facilitate students in answering the last question - the core problem of this topic. This concept was taught in high school by first introducing the concepts of work and potential energy. The introduction of these concepts was based on an analogy between gravitational field and electric field. The concept of electric potential was then defined as work per unit charge. Therefore, students only memorized this term and they were more likely to forget it. The findings of this topic proved this fact. It appeared very difficult for students to grasp this concept through this demonstration. The findings showed that none of students was able to explain why the flash is brighter when the metal plate is grounded at some distance from the plastic base. Many students implied that a larger amount of electric charge flows through the charge detector, but they failed to give the reason for the excess of electric charges. From the activity sheets, some students' misconceptions were identified. Some students thought that electric charges are transferred from the plastic base to the metal plate by conduction when the metal plate is placed on the charged insulating base. The others implied that there exists charge transferability in the opposite direction from the metal plate to the insulating base. This revealed students' inadequate understanding of the basic knowledge of electrostatics.

At the beginning of the concept introduction phase, most students had not found the answer for the last question, although they had two days to think about it. Therefore, the teacher had to raise some questions to lead students to the formation of this concept from the demonstration such as: Is there any charge transferability between the metal plate and the insulating base? Why? Is the metal plate charged after being grounded? Explain why? What happens when the metal plate is lifted away from the plastic base? Has any work been done on the charges of the metal plate when it is lifted away from the base? If work has been done, which energy will it transfer to the electric charges on the metal plate? The discussion of the first question was very exciting, but it did not lead to the results the teacher expected. None of students realized that since the plastic base is flat and the points of contact with the metal plate are few, electric charges cannot be transferred between the metal plate and the insulting base by conduction. At this juncture, some students were able to answer the second question by visualizing the electrostatic induction existing in the metal plate and the process of charging by induction. It was not too difficult for them to realize that the like charges that are on the plastic base (negative charges) are induced to the top of the metal plate, these induced charges are removed when the metal plate is grounded, and then the metal plate is charged by induction.

The next two questions reminded students of the concept of work. Without this question, it was impossible for students to conceptualize work done on electric charges when the plate is lifted from the base. To answer the last question, some students stated that when work has been done on electric charges, it will transfer thermal energy to the metal plate and make it hotter. This results in the appearance of the excess of free electrons, therefore, a larger amount of electric charges flows through the charge detector producing the brighter flash. At this point, the teacher had to raise one more question: Where does the thermal energy come from - from lifting or from rubbing? At this moment, the teacher helped students recall the conservative law of energy to show that this energy is potential energy. By correctly answering these questions, students naturally recognized that the electric charges on the metal plate at the separate position gain more energy than at the previous position. Finally, the teacher led students to the conclusion that when the metal plate is lifted away from the plastic base, work has been done on the charges. This work results in giving the charges a higher potential relative to the ground, Therefore, when the metal plate is grounded in the separate position, the charges are transferred at a higher potential and more energy will be released, producing the brighter flash from the charge detector. This demonstration helped students grasp the meaning of the electric potential: the work done by the electric field using scientific reasoning instead of memorizing its definition. Most students expressed their interests in this class session because the acquisition of this concept shows them the reason for the definition of the term "electric potential" and explains its mathematical expression, as presented in the physics textbooks.

In the application phase, the demonstration was very similar to that in the exploration phase. The purpose of this demonstration is to check students' understanding of the concept of electric potential. The findings showed that 46% of students revealed their comprehension of the concept of electric potential. The remainder exposed inadequate understanding. One student expressed his idea related to the change in his prior conceptions in his journals:

> Before experiencing this demonstration, I thought that the transferability of electric charges from one place to another comes from differences in the amount of electric charges. This demonstration made me understand that the charge transferability from one place to the other is due to the differences in electric potential. It formed new conceptions in my mind. Therefore, I am interested in this demonstration, and I know what benefits it brought to me.

In terms of Lawson's terminology, in the exploration phase, all students failed to discover the "pattern" by themselves. In the second phase, the teacher had to guide them by raising many questions to help them to identify the concept. By this way, the "pattern" was gradually formed in the students' mind. Finally, students' perception of this concept was enhanced through demonstrations and the learning cycle. One of the reason accounting for students' difficulties in identification of this concept was that the introduction of the term "electric potential" referring to the above "pattern" required prior knowledge such as work done by conservative force, potential energy, and conservative law of energy as well as the syntheses of knowledge in the new context. This revealed students' weak background, and their inability to synthesize prior knowledge stemming from the lack of higher order reasoning patterns.

Properties of conductors in electrostatic equilibrium

In this topic, because of the breakdown of the Van De Graaff generator, exploration demonstrations (topic 3, p. 63) were verbally described by the teacher. The findings showed that:

- 11% of students applied their previous knowledge (the electrostatic induction, the superposition principle of electric fields) to explaining why there is no electrostatic field inside a metal hollow globe if it does not contain any electric charge. The remainder (89%) gave incomplete explanations.
- About 8% of students successfully explained why there is an electrostatic field inside the metal hollow globe if there exists electric charges inside it.
- All students were unable to infer any conclusion from experiments a and b.
- There were no students who gave plausible descriptions to explain why there is no electric field inside the hollow globe after it is connected with the small charged conductor inside it by a conducting wire.
- All students also failed to answer question 5 involving the second property of conductors (electric charges on a conductor only exist on its outer surface).
- All students were unable to answer question 6 related to technological applications.

The answer to the questions in this exploration demonstration required students to recall their previous knowledge and to apply it to their explanations. The earlier analyses proved that more than 58% of students acquired knowledge of electrostatic conduction, but they did not know how to use it in this instance to explain physical phenomena, except for very few students. However, the demonstrations together with these questions seemed to inspire them to deeper thinking and they really made progress in class discussion after two days. With a few questions raised by the teacher, students' previous knowledge appeared to be recalled gradually and some students easily explained experiment a.

When discussing the second question involving experiment b, most students did not recognize the existence of two kinds of induced charges on the hollow globe with different distributions: one is caused by the outer charge, and the other one is due to the inner charge. Therefore, all of them also failed to perceive the existence of two different electric fields inside and outside the hollow globe: the inner field is due to the inner charge only, but the outer field is caused by both inner and outer charges. Most students only understood the physical phenomena involving experiment b with direct guidance from the teacher. An important aspect implied in experiments a and b were not identified by most students. It seemed complicated for them to figure out. These experiments demonstrate that no electrostatic charge outside can create any electric field inside a close conductor, but electrostatic charges inside a closed conductor can still produce an electric field outside. The fact that most students were unable to recognize this implication in experiments a and b can be understood from Piaget's point of view. At that time, for most students, a substantial part of knowledge obtained from experiments a and b was constructed in their minds by the teacher, not by the students themselves. Therefore, this knowledge has not been assimilated and firmly accommodated in students' mind. In the very short time in the class discussion, there was not enough time for them to manage and organize their knowledge in order to explore new information.

Through class discussion, it seemed not too difficult for students to infer the second property of conductors from experiments c and d. However, at the beginning, some students had trouble with deducing the direction of the motion of free electrons in the conducting wire from given charge distributions in experiment c. This means that they did not know how to infer that free electrons will move from where to where. Most students were interested in technological applications, but they were unable to figure them out without the direct guidance from the teacher. The class session continued with the use of the mathematical expressions learned in the previous topic involving the relationship between electric field and electric potential, and work done by electric force to derive the third and fourth properties of conductors. These learning activities were directly guided by the teacher.

The first two experiments a and b in the application phase were offered to check the extent to which students understand the first two properties of conductors. From the activity sheets, about 35% of students gave plausible descriptions to interpret experiments a and b on the basis of the synthesis of previous knowledge such as the electrostatic induction, the characteristics of the electric field vector, and those of conductors. There were more than 35% who gave absolutely intuitive explanations without any conscious reasoning. Experiment c was designed to check the students' ability to use knowledge just learned to explain new phenomena. About 24% revealed this ability, and 30% of them exposed inadequate understandings of basic knowledge of electric phenomena.

Electromagnetic induction and Lenz's law

In the exploration phase, based on the activity sheets, there were 10% of students who raised relatively appropriate reasons for explaining the appearance of induced currents. They thought that experiments 1a, 1b, and 2 (p. 68) proved the existence of a changing magnetic field around the solenoid while the magnet or the solenoid was moving, or around the loop while the area confined by the loop was changing. At this point, these students did not recognize the difference between the first two experiments in demonstration 1 and the experiment in demonstration 2. The former demonstrate the change of the magnetic field in the proximity of the solenoid. The latter illustrates the change of the area of the surface bounded by the loop, but not the change of the magnetic field. During the discussion in small groups in the physics lab, some students proposed another experiment, beyond the experiments written in the materials, to get more information for their explanations. They placed the magnet and the solenoid at stationary positions with one another, and then turned around the magnet or the solenoid. They also changed the angular velocity of one of them, and the direction of the rotation to examine the magnitude and the direction of the induced currents. In this case, students also concluded that the appearance of the induced currents is due to the change of magnetic field. They did not pay attention to the change of the direction of the magnetic field relative to the axis of the solenoid.

There were more than 9% of students who logically inferred the factors affecting the magnitude and the direction of the induced currents. They stated that the magnitude of induced currents depends on the rate of change of the magnetic field, and their direction depends on the fact that the magnetic field is increasing or decreasing. Although students learned these phenomena in high school, but they could not recall their prior knowledge. Dealing with the application of electromagnetic induction, more than 25% of students gave correct descriptions and explanations of the operation of the electric generator, and nearly 23% correctly interpreted the operation of the electric motor.

In the class discussion of the second phase, the teacher helped students combine all their reasonable conclusions to lead them to discovering the general reason for the appearance of the induced currents. The following conclusions were drawn from the class discussion with high consistency from many students: the appearance of the induced currents is due to the change of at least one of the three factors as follows:

- The change of the magnetic field demonstrated in experiment 1a.
- The change of the area confined by the loop illustrated in experiment 1b.
- The change of the angle between the direction of the magnetic field and the axis of the solenoid shown by the additional experiment suggested by some students.

These analyses naturally resulted in the formation of the concepts of magnetic flux covering the above three factors. This concept is one of the basic concept of electromagnetic phenomena. It was induced from a thorough generalization of all of the students' reasonable explanations. By this way, students constructed knowledge by themselves with a little guidance of the teacher. Accidentally, the additional experiment proposed by some students created the adequacy of the instructional design in topic 4, and therefore, contributed a substantial part to the formation of the concept of magnetic flux.

The class session continued with the discussion of the magnitude and the direction of induced currents to lead to the introductions of Lenz's law and Faraday's law. Since they had all had experiences in the exploration phase, it seemed that they quickly acquired these physics laws. The class also discussed technological applications related to these phenomena such as the possibility of converting mechanical energy to electric energy in the formation as well as the operation of electric generators, and the possibility of reconverting electric energy back to a mechanical form in the formation of electric motors. Students seemed interested in these applications. Although they were taught the operations of these machines in high school, but a large number of students were unable to remember what they learned.

Experiment a and the first question in the application demonstration is to check students' understanding of the electromagnetic induction. 68% of students explained this experiment using concept of magnetic flux. The small group discussions in this phase were more exciting than those in the exploration phase because they gained more experiences in explaining these phenomena. Experiment b, together with the second question is designed to give students the practical meaning of Lenz's law (a magnetic force that exerts on induced currents in a magnetic field tends to oppose the motion which produces them). There were 62% of students who interpreted this fact on the basis of firmly grasping Lenz's idea. They revealed their interests in this experiment.

Experiment c challenged students with the electromagnetic induction in a new situation in which there are no motion of the small coil relative to the electric magnet. The findings indicated that about 61% explained that the alternating current in the electric magnet changes its direction 100 times a second and produces a changing magnetic field in the proximity of the small coil (in Vietnam, the frequency of alternating currents is 50 Hz). They gave a very good explanation. Experiment d and the last question were offered to help students enhance their observation skills and scientific reasoning skills. This experiment opened an interesting discussion in small groups about the effects of the different number of turns. They gave many different explanations, however a few students guessed the right answer. In this phase, students revealed their good ability to explain the operations of new models of the electric generator and motor. About 60% of students gave good descriptions about the operation of the electric motor, and 66% gave plausible explanations for the operation of the electric generator.

Eddy current and its technological applications

The exploration demonstration 1 in topic 5 (p. 70) required students a synthesis of previous knowledge, a scientific reasoning ability, and a highly abstract level of thinking. Based on the findings, there were about 12% of students who properly used Lenz's law to explain why the aluminum ring leaps in the air (experiment a of the exploration demonstration 1).The remainder 88% gave vague explanations. None of students correctly explained the levitation of the ring, and therefore they were unable to explain why its levitation is not stable in the direction perpendicular to the core. All students did not recognize the two components of induced currents existing in the ring. One is caused by the sudden change of the current in the solenoid, in a very short time at the beginning, when the variac is switched on. This is the reason for the leap of the ring. The other one is due to the change with time of the alternating current in the solenoid. This is the cause for the levitation of the ring. Most students easily understood why the two aluminum rings attract each other while levitating in the air because they all knew the magnetic interaction between two currents.

All students described and explained correctly experiment b with the aluminum ring that has a cut through it. Some students suggested a comparison of the required minimum alternating voltages supplying for the solenoid to lift an aluminum ring, an aluminum cylinder, and a ring cut from an aluminum foil. They inferred that the larger the size of the ring, the smaller the required minimum voltage to lift it. They made more useful observations, but they failed to recall prior appropriate knowledge for their explanations even though this knowledge is very simple, very easy to understand and memorize (the property of the resistance of conductors: the larger the size of a conductor, the smaller its resistance, and the Ohm's law). There were about 5% of students who gave the correct explanation for the rest of experiment b.

It was not too difficult for students to answer why the water boils in experiment c with the illustration of Joule heating. None of students were able to give plausible descriptions for explaining experiment d. It seemed very difficult for them to figure out this phenomenon. Some of them neglected the existence of the induced currents in the copper disc. The others took account of this, but they failed to determine the direction of the magnetic force exerting on the copper sphere due to these induced currents.

Dealing with experiments a and b in the exploration demonstration 2, there were 15% of students who correctly described why the copper disc rotates slower in the magnetic field than it does in the air using Lenz's law. Among these students, there were 5% who gave detailed descriptions of the direction of the induced currents and that of the magnetic forces exerting on them. Most students misunderstood when answering the second question related to experiments b and c. They thought that there are no induced currents in the slotted disc when it rotates in the magnetic field because the data recorded in experiments a and c are the same. No one was able to answer question 3 referring to technological applications.

Although the findings showed that the students' ability to explain physical phenomena was low in experiments a, b, and d (in demonstration 1), the small group discussions in the physics lab were more exciting than ever before. It seemed there was not enough time for their discussions. Therefore, the teacher deserved more time for them. Some students were inspired by these experiments so strongly that they were not patient enough to wait until the next two days for the class discussion. They returned to the physics lab the next day to attend the group discussion with the other groups.

In the second phase, journals of many students indicated that students entered the class with inspiring thoughts. Two components of induced currents existing in the ring were raised first by the teacher for students to discuss. All students were interested in this phenomenon. Many students revealed their good ability to use Lenz's law and knowledge of magnetic forces in their interpretations. By clearly indicating the direction of induced currents using Lenz's law and by analyzing magnetic forces exerting on the induced currents, students explained why the ring leaps and levitates in the air. And therefore, they were able to understand why the levitation is not stable in the direction perpendicular to the core axis. The class session continued with the discussion about the rotation of the copper sphere in the water when the copper disc is slipped under the beaker to shade part of the core. At the beginning, the class was quite silent because none of the students had found the answer. However, when the teacher gave vague and intuitive explanations for the rotation of the sphere, some students immediately identified unreasonable factors in the teacher's arguments. The class atmosphere became more and more exciting, and more and more students attended the debate. Students actually made progress in their reasoning. With a few questions raised by the teacher, some students easily found the answers for themselves. The class discussion ended with students' expressions of interest and pleasure.

In the application phase, the discussions in small groups were also interesting. Regarding to application demonstration 1, the findings showed that about 62% of students gave clear descriptions in answering the first question involving experiments b and c. More than 69% of students gave the right answer for the second question involving experiments d and e. Some students properly used Lenz's law and knowledge of magnetic force in their explanations. They clearly indicated by logical reasoning that the magnetic force on the induced currents in the aluminum tube is downward and that in the magnetic bob is upward. That is the reason why the weight of the aluminum tube becomes heavier, and the magnetic bob is moving more slowly in the aluminum tube. Other students seemed to be penetrated with Lenz's idea by reasoning that when the magnetic bob is moving in the aluminum tube, it creates a changing magnetic flux and produces induced currents in the tube. These induced currents tend to oppose the cause producing those currents. That is the relative motion of the bob toward the tube. Therefore, the tube is pulled into motion in the same direction of the bob to decrease the relative speed between the bob and the tube. This effect makes the tube heavier. This means the magnetic bob exerts a force downward on the tube. According to Newton's third law, the tube naturally exerts a force upward on the bob, and makes it move more slowly.

The discussion was expanded beyond what the teacher required them to do. Some students reasoned intelligently that since the magnetic bob begins falling with constant acceleration, its velocity increases more and more. This results in the quick increase of the magnetic force exerting on the bob. Therefore, after a very short time from the moment the bob dropped, the magnetic bob reaches a terminal velocity. At that time, the sum forces on the bob must be zero. Thus the weight of the bob must equal the magnetic force exerting on it due to the induced currents in the aluminum tube. In accordance to Newton's third law, the upward force on the bob has an equal and opposite force downward on the tube. This force is equal to the weight of the bob from the terminal velocity condition (if the bob "floats" down the tube without touching its sides). As a result, when the bob is falling in the tube, the weight of the tube is increased an additional amount that is equal to the weight of the bob. This showed that students got involved more and more thoroughly in the learning activities, and they really made progress in critical thinking skills as well as scientific reasoning skills. The remainder (38%) gave inadequate explanations. These students still had trouble with the use of the Lenz's law.

The application demonstration 2 challenged students with new experiments resulting in technological applications. Since most students experienced similar demonstrations in the exploration phase, it was not difficult for them to explain these phenomena. The findings revealed that about 70% of students correctly answered all the questions. Most students were interested in investigating some structures of electrical meters to see how physical phenomena apply to technology.

From the above descriptions, the evolution of students' understanding of the physical concepts and principles can be illustrated in table 2:

Table 2: The evolution of students' understanding of the physical concepts and principles

Physical concepts and principles	*Exploration phase*	*Application phase*
Electric charge	13%	64%
Polarization	4%	54%
Electrostatic induction	3%	58%

Electric potential	0%	46%
Properties of conductors: Electric field	11%	35%
Properties of conductors: Charge distribution	7%	35%
Electromagnetic induction	10%	68%
Lenz's law and Faraday's law	9%	62%
Eddy current	12%	62%
Average	8%	56%

How students understand the physical concepts and principles

In the exploration phase, student's answering the questions on the activity sheets, on the one hand, reflected the adequacy or inadequacy of their prior conceptions, on the other hand, exposed their reasoning skills and/or ability to synthesize prior knowledge to explain new phenomena. On average, only 8% of students could do this successfully. It should be noticed that the percentage listed in table 2 indicated partial students' understanding of the concepts or principles listed on the first column but not complete understanding. This might be because students mainly learned high school physics through taking notes, reading physics textbooks, and then trying to remember the science facts to cope with the exams rather than through learning environments that promote self-constructing knowledge to result in the deep understanding of scientific knowledge. Moreover, most of them were average and poor students (nearly 80%), therefore, it seemed hard for them to discover the concepts and principles with minimum guidance of the teacher. Most students appeared unfamiliar with self-discovery. At high school, the traditional method of teaching has not provided students with opportunities to engage in concrete experiences, and to encounter new phenomena. As a result, the new information was not assimilated. Then, there was no place for new information to be processed to produce changes in students' mental structures. In other words, the traditional teaching method did not promote disequilibrium and self-regulation to arouse the development of students' mental structures that enable the enhancement of understanding of scientific knowledge and the development of higher order reasoning patterns.

The most difficult concept for students was electric potential. This is probably because the acquisition of this concept through the designed demonstration required a combination of lots of students' abilities such as observations, logical thinking, and the retention of prior knowledge, especially the use of analogical reasoning. It was impossible for average and poor students to reach these abilities because students cannot discover the analogy without the teacher's assistance in forming theoretical concepts such as the concept of electric potential. This concept was taught at high school by simply verbally introducing to students the term which represents the concept after introducing the concepts of work and potential energy by using the analogy between the gravitational field and electric field. The easiest concept was electric charge because the grasp of this concept does not require much prior knowledge. It should be reminded again that the findings showed students' poor retention of prior knowledge. The formation of this concept comes merely from properties inferred from observed interactions that students had experiences through demonstration experiments.

The low percentages that were recorded for the concepts of polarization and electrostatic induction derived from the fact that most students were unable to visualize and comprehend the role of electric charges in the structure of matter. The fact that the percentages slightly increased in the last half of the pilot teaching period accounted for students' gaining more experiences in observation skills, reasoning ability, as well as ability to synthesize prior knowledge.

In the application phase, on average, 56% of students relatively acquired the understandings of physical concepts and principles of the course. This percentage exceeded the percentage of fairly good students (0.7%), and that of near average students (13.3%), and approximated to the percentage of average students (58%). This means that a substantial percentage of average students were able to make sense of these concepts and principles. In this phase, the lowest percentage was recorded for the comprehension of properties of conductors. This is probably because the application demonstrations involving properties of conductors required students to use higher order reasoning skills in the synthesis of previous concepts and knowledge such as the concept of electric potential, characteristic of electric field vector, and the relationship between them. It should be noticed that the percentage of students understanding the concept of electric potential was greater than that grasping the properties of conductors. This fact indicated that although students understood the concept of electric potential but they were unable to use this concept to explain new phenomena.

In terms of Piaget's theory, in general, the percentages of students assimilating and accommodating new knowledge relatively decreased from the concept of electric charge to the properties of conductors in the order presented in table 2. The reason was that the understanding of the concept of electric potential and properties of conductors required students to have a higher level of thinking. The comprehension of such knowledge did not require the assimilation and the accommodation of data only from concrete experiences but also from abstract reasoning with verbal elements relevant to the stage of formal operations. At their ages, around 20 years old, they should have entered this stage of formal operational thought in which they are capable of thinking “beyond the present” and forming “ theories about everything, delighting especially in considerations of that which is not” (Piaget, 1966, p. 148). However, for many reasons beyond the scope of this thesis, students experienced difficulty in understanding abstract concepts. The understanding of the first three concepts (electric charge, polarization, and electrostatic induction) required a lower level of thinking to accommodate these conceptions to reach the equilibrium in their mental structure. Therefore, more students self-regulated with these concepts.

For electromagnetic phenomena, the percentage of students reaching the equilibrium in their process of perceptions slightly increased. This reflected that more than 60% of students became accustomed to a new learning environment that promoted self-discovery and the development of abstract reasoning skills. Activity sheets, students’ journals, as well as group and class discussions showed the increase in students’ creative thinking and scientific reasoning skills through explaining physical phenomena. That was the reason why more students gained insight into scientific knowledge.

Students’ perceptions of technological applications

Table 3: Students’ perceptions of technological applications

Technological application	*Exploration phase*	*Application phase*
Properties of conductors	0%	
Generator	25%	66%

Motor	23%	60%
Eddy current	0%	70%
Average	24%	65%

Properties of conductors

In the exploration phase, when being asked about the applications of the properties of conductors in technology, all students did not have any idea. They have seldom realized that what they learned in school can apply to their life because the physics teaching at CGS, as well as the physics textbooks failed to emphasize the relationship between physics and technology. Students were accustomed to studying pure physics. In the term introduction phase, when the technological applications had been introduced, most students revealed their interests in these issues, especially the principle of "shielding" electrical equipment by placing it in a metal can. The idea of this technological application was expanded by raising the question: "Does electrostatic shielding work both way?" extracted from Feyman's statement in Feyman lecture on physics:

> We have shown that if a cavity is completely enclosed by a conductor, no static distribution of charges outside can ever produce any field inside. This explains the principle of "shielding" electrical equipment by placing it in a metal can. The same argument can be used to show that no static distribution of charges inside a closed conductor can produce any field outside. Shielding works both ways!. (Feyman, 1964, pp. 5-9).

The statement above was given to students to "think about." The instructor's intention was to raise Feyman's idea of two-way shielding as a question to engage students, and, indeed, the statement provoked them to actively participate in the class discussion. As a result, students recognized the implication of experiments a and b in the exploration demonstration in topic 3 (pp. 63-64), being asked by the third question. It seemed that the practical meaning of physical phenomena stimulated students for further investigations. In students' journals, one student stated:

> I am interested in technological applications. That is the reason why I want to specialize in engineering. The way the physics textbooks presented technological applications did not motivate my attentions. The physics demonstrations forced me to think a lot about the physics lectures, especially the ones related to technological applications. These applications help me realize why I need to study physics, and how physics benefits the development of technology and society.

Dealing with the experiment e related to the method used to produce large potentials in the Van De Graaff generator in which the charges are brought to the inner surface of a large spherical conductor by a continuous charged belt, one student wrote in his journals:

> I was very surprised why this simple demonstration can lead to an attentive application in technology. I knew and I heard about this electrostatic generator, but I can not imagine that this machine was created from a very simple idea.

This statement shows that technological applications, even though very simple, seemed so strange for some students.

Electric generators and motors

The application of Faraday induction law to generate electric energy in society, and to lead the formations of electric generators and motors was taught in grade 12. This topic has been one of the main components often dealt with in entrance university examinations. Therefore, students who passed this entrance exam should have known this application. However, the findings showed that only more than 24% of students have still retained this knowledge. These applications have been usually taught with the figures drawn in the textbooks or on the blackboard, and with the descriptions in the textbooks or verbal descriptions of the teacher. Students had no chances to observe the real models of generators and motors. In the exploration phase, students had the opportunity to investigate very simple models of these electric machines. These concrete experiences with these models made students firmly understand the principles by which electric generators and motors operate with just a little guidance of the teacher.

In the application phase, students were challenged with new models of electric generator and motor. Students obtained more experiences in explaining operational principles of the electric machines. The finding showed that about 70% of students gained insight into these applications.

Eddy currents

In the exploration phase, students were interested in exploration demonstration 2 in topic 5 (pp. 72-73). About 15% of students successfully explained the slower motion of the copper disc in the magnetic field. But none of the students were able to figure out how this phenomenon can apply to technology. In the term introduction phase, when being asked the way this phenomenon can apply to technology, just a few students revealed their perception of these applications. One journal keeper wrote:

> The last question in the exploration demonstration forced me to think about technological applications of physical phenomena. Therefore, I tried to seek information by reading some textbooks. By this way, I felt interested in studying physics because I realized that what I learned can benefit my future career. It seemed that there were very few textbooks in the CGS library, and technological applications in these textbooks were presented very cursorily.

In the application phase, more students were able to explain the damped oscillation of the copper and aluminum pendulums on the basis of determining the magnetic force exerting on eddy currents in these pendulums. Some students imagined that the presence of drag force makes the motion of the copper pendulum in the magnetic fields analogous to the motion in a viscous medium. Most students were interested in looking inside electrical meters to see how eddy currents are applied. In students' journals, most of them revealed that these learning activities promoted students to actively study physics because they realized the usefulness and the practical meaning of physical phenomena.

In summary, in the exploration phase, most students revealed weak perceptions of the relationships between physical phenomena and technological applications (24%). In the application phase, about 65% of them had stronger perceptions of these relationships. These perceptions contributed partly to encouraging students in studying physics.

Students' attitudes toward learning physics with demonstrations

In formal words, attitudes are complex human states that affect behavior toward people, things, and events (Gagne, Briggs, & Wages, 1992, p.86). In this study, the researcher only deals with the affective aspect of attitudes referring to students' feelings and ideas toward learning physics with demonstrations. The analysis of students' attitudes is based on attitude measure drawn from the questionnaires and attitude assessment inferred from observations in integrating with the results from the questionnaires, and from teacher's and students' journals.

In the last day of the class, students were asked to complete a questionnaire of 20 items concerning the enjoyment of physics, motivation in physics, and value of physics in their future career. There were 80 returned copies of the completed questionnaire out of one hundred. The results of the attitude scale are presented in table 4 as follows:

Table 4: The results of students' attitude scales

Enjoyment of physics	SA	A	U	D	SD
1) I feel interested in learning physics.	27%	53%	17%	3%	0%
2) Physics is not an interesting course.	1%	5%	17%	30%	47%
3) I enjoy studying physics with demonstration experiments.	53%	30%	15%	2%	0%
4) I fear to study physics with demonstration experiments	2%	3%	13%	33%	49%
5) I would like to do demonstration experiments related to technological applications.	65%	33%	2%	0%	0%
6) I would like to spend more time in studying physics	46%	36%	14%	2%	2%
7) I feel interested in learning activities in the physics laboratory.	48%	45%	5%	2%	0%
8) I would like to spend less time in the physics laboratory doing demonstration experiments.	0%	2%	13%	32%	53%

Motivation in physics	SA	A	U	D	SD
9) I think I need to study physics.	50%	46%	2%	2%	0%
10) I am taking physics course because I want to complete my undergraduate degree.	15%	33%	42%	5%	5%
11) Demonstration experiments help me more clearly understand physics lectures.	52%	38%	7%	3%	0%
12) It is hard for me to comprehend physical	21%	28%	37%	12%	2%

concepts and principles					
13) Physics with demonstration experiments involve interesting and funny things.	53%	40%	5%	0%	2%
14) Demonstration experiments motivate my curiosity, and force me to think more about the lectures.	55%	40%	3%	0%	2%
Value of physics course for student's career and life	**SA**	**A**	**U**	**D**	**SD**
15) I found nothing useful when studying physics.	3%	3%	17%	30%	47%
16) Physics is very necessary for my future career.	48%	38%	12%	2%	0%
17) Technological issues are closely related to knowledge of physics.	42%	53%	5%	0%	0%
18) I think I can apply knowledge of physics to my work after graduation.	42%	40%	16%	2%	0%
19) Engineering students must have basic knowledge of physics.	65%	33%	0%	2%	0%
20) Only physicists or physics teachers need to have knowledge of physics.	0%	0%	10%	33%	57%

With regard to enjoyment of physics, 80% of students felt interested in learning physics, and 77% of them disagreed or strongly disagreed with the statement: "Physics is not an interesting course." There were 17% of students who did not expose their ideas for both of these statements. About 82% of students would like to spend more time in studying physics. The percentage of students who revealed their enjoyment of learning physics with demonstrations slightly increased (83%). 82% of students disagreed or strongly disagreed with the statement: "I fear to study physics with demonstration experiments." 13% of students did not give their ideas about this statement. Most students (98%) were interested in doing demonstration experiments related to technological applications because they all would like to specialize in engineering. 93% felt interested in learning activities in the physics lab. 85% exposed their disagreement or strong disagreement with the statement: "I would like to spend less time in the physics lab doing demonstration experiments." The students' enjoyment of learning physics with demonstrations was clearly exhibited through almost all learning activities in the physics lab as well as in group or class discussions. In his journal, one student wrote:

> Doing demonstration experiments is the most interesting component of the course. I did do demonstration experiments and watch real physical phenomena with my own eyes. By this way, many questions rose in my mind and forced me to think more and more about them. But I regretted that it did not have enough time for me and other students to do additional experiments that we thought out by ourselves to verify some hypotheses.

Most journal keepers suggested increasing the time for doing demonstrations, and the time for group and class discussions. One of these suggestions is:

> Group and class discussions are very beneficial and interesting because they encouraged students to seek for evidence to explain physical phenomena. They inspired students to share ideas, to dispute with their peers. They forced all students to actively debate to defend their ideas, and made the class atmosphere more and more exciting. However, it was to be regretted that there were not enough time for most students to present all their ideas.

Dealing with motivation in physics, more than 96% of students agreed and strongly agreed that they need to study physics. About 48% of students showed their positive attitude to the statement: "I am taking physic course because I want to complete my undergraduate degree." 42% of them did not expose their ideas about this. Only 10% of students expressed their disagreement or strong disagreement with this statement. This means that half of students who perceive the necessity of studying physics because they want to complete their degrees. These students underplayed the role of gaining knowledge in favor of obtaining degrees. Only 10% of students mentioned the purpose of studying physics as the actual acquisition of knowledge.

More than 90% of students acknowledged that studying physics with demonstrations involved interesting and funny things, and these demonstrations motivated their curiosity as well as forced them to think more about the lectures. 90% of students admitted that demonstration experiments helped them more clearly understand physics lectures. However, about 49% of them still felt that it was hard for them to comprehend physical concepts and principles. Although demonstrations with the learning cycle created opportunities for students to construct knowledge by themselves with the expectation that they really deeply understand the basic knowledge of physics. However, the findings in the previous sections indicated that it has still been hard for students to self-construct knowledge without the direct guidance of the teacher. This might be because it is the first time students have engaged in such a new style of learning, and just in a very short period of time. Furthermore, there was not enough time for the new ones to penetrate into students' way of thinking to form a thorough transformation into students' cognitive strategies, capabilities that govern the individual's learning, remembering, and thinking behavior (Gagne, Briggs, & Wager, 1992, p. 44). Cognitive strategies are special and very important skills, and such skill will improve over a relatively long period of time as the individual engages in more and more studying, learning, and thinking (Gagne, Briggs, & Wager, 1992, pp. 44-45).

In terms of value of the physics course for student's career and life, 98% of students agreed that engineering students must have basic knowledge of physics, and 95% of them thought that knowledge of physics has a close relationship to technological issues. 86% perceived that physics is very necessary for their future career, and 82% of them thought that they could apply knowledge of physics to their work in the future. 90% of students recognized the importance of physics knowledge in society when expressing their disagreement with the statement: “Only physicists or physics teachers need to have knowledge of physics.” However, only 77% of them revealed their disagreement with the statement: “I found nothing useful when studying physics.” 10% of students either doubted the applicability of physics knowledge they just learned or have still not conceived of how useful knowledge of physics has been.

In summary, most students expressed positive attitudes toward studying physics with demonstrations. They also perceived the crucial role of demonstrations in enhancing the comprehension of physical concepts and principles. They were interested in technological issues stemming from the laws of physics. However, half of students still favored studying for exams rather than studying for knowledge itself. Half of them still felt difficult to understand concepts and principles of physics.

The above discussions was a general assessment of students’ attitude and their perception of some aspects of studying physics with demonstrations. These ideas were obtained from completed questionnaires implemented after the last very exciting class discussion. All students exposed their positive attitude toward completing the questionnaires beyond the researcher’s imagination. The ebullient atmosphere of the class discussion that day might have partly influenced the results drawn from the questionnaires.

Chapter VI

Conclusions and implications

This chapter is devoted to summarizing the major findings and results presented in Chapter 5. A general assessment of the instructional design is also dealt with in this chapter. The limitations of the study are then discussed. Finally, the implications of the research are addressed for further study in science education.

Summary of major findings and results

The data analyses in Chapter 5 provided a general view of the evolution of students' understanding of physical concepts or principles through 3 phases of the learning cycle. In the exploration phase, the findings showed that students revealed misconceptions, weak high school background, and poor thinking skills. Only 8% of students were capable of discovering partly the "patterns" of the physical concepts dealt with in the instructional design. This phase suggested useful topics for the class discussion in the next phase. In the term introduction phase, before introducing the "terms" of these concepts, the teacher had to help students continue to discover or identify the "patterns" of these concepts by raising additional questions. It appeared difficult for students to construct knowledge by themselves without the direct guidance of the teacher. In the application phase, students exhibited their interests in applying what they just learned to explaining new physical phenomena. About 56% of students gained more understanding of physical concepts and laws of physics. They made progress in their scientific reasoning and critical thinking skills.

In the last half of the pilot teaching period, learning activities with demonstrations and the learning cycle stimulated students' interests and curiosity, and provoked them to actively participate in the learning process. They revealed their progress in self-constructing knowledge through observing demonstration experiments and answering the related questions. However, nearly 50% of students, especially poor and very poor students, still felt uncomfortable participating in the constructive process to improve their acquisition of knowledge. Students got involved more and more in the learning activities in the physics lab with small group discussions, as well as in the large class with class discussions.

Students also exposed their interests in demonstration experiments that illustrate the relationship between physics knowledge and technological issues in society. In the exploration phase, students revealed poor understandings of practical meaning of what they learned in school. However, in the second and third phases, most students expressed their interests in technological aspects of physics knowledge. These interests can be seen as one of the important factors to motivate them to study physics because the understanding of scientific concepts would probably be enhanced by the study of technological applications.

Most students appeared to have enjoyment and motivation for studying physics with demonstrations. They also recognized the importance of lecture demonstrations in reinforcing the understanding of scientific knowledge. Students' positive attitudes toward physics were revealed through their perceptions of the necessity of physics knowledge and that of value of physics in their future career. Yet half of them still considered studying for exams to be of great value.

Two midterm tests and the final exam were designed in form of multiple choice questions. In these tests, nearly 70% of students correctly answered the questions requiring definitional knowledge of science facts or laws of physics. About 37% correctly answered the questions requiring critical, scientific thinking. This demonstrated that 63% of students revealed low performance in these areas.

Although 90% of students felt interested in learning physics with demonstrations, only 56% were able to grasp basic concepts and laws of physics. The remainder still had difficulty with these physical concepts and laws of physics. The instructional design with demonstrations and the learning cycle provided students with advantageous conditions and a better learning environment to facilitate their acquisition of knowledge and to promote their learning. However, this design is only the necessary condition to enhance the effectiveness of students' learning physics. The sufficient condition would be the students' minimum ability to attain knowledge from the designed learning environment. This design was tested in the class comprising nearly 80% of students who were average and poor students. Therefore, a high percentage of students' good performance cannot reach on this population.

A general assessment of the design

In this section, a general assessment of the design was implemented on the basis of the findings and the researcher's viewpoint. This assessment focuses on two aspects: what benefits demonstrations brought to students and how useful the learning cycle was in promoting students' learning science.

What benefits demonstrations brought to students

Data analyses from different sources indicated that many students consistently mentioned lecture demonstrations as the most interesting aspect of the physics course. They all perceived the important role of demonstrations in their learning. In their journals, some students remarked on how demonstrations helped them to visualize and think about physics. Others mentioned that demonstration experiments made the class interesting and helped them to remember the material. Many ideas referred to benefits that demonstrations bring to students such as: "Demonstrations helped to get me think a lot about the lessons," "Demonstrations helped me learn better because they gave me practical examples in which I can visualize the problems and solutions," "Demonstrations helped me understand how physics relates to technology."

Another useful aspect of demonstrations not mentioned by students was that some demonstrations helped students to make the connection between the phenomenon and the mathematical equation used to describe it. For instance, from the demonstration experiment on the concept of electric potential, if the conclusions were correctly drawn from this demonstration, then they would lead students to the understanding that electric potential is mainly work done by the electric field. This demonstration is very beneficial in showing students the reason for the definition of electric potential in any physics textbook, and then relating the results drawn from this demonstration to the mathematical expression used to describe these phenomena. This demonstration would contribute to making students clearly understand the meaning of the mathematical equation expressing this concept of physics.

After a few weeks of learning physics with demonstrations, some students clearly exposed their creative thinking skills by suggesting additional experiments to get more information and evidence for their explanations. The first one suggested by students relates to the demonstrations of the electromagnetic induction phenomenon. Fortunately and accidentally, this suggestion partly supplemented the deficiency of the instructional design (see chapter 4, pp. 67-68, and chapter 5, pp. 87-88). This additional experiment facilitated the teacher's introduction of the term "magnetic flux" and helped the teacher make a very beautiful link between the phenomenon and its mathematical representation. In this way, the teacher led students from observable physical phenomena to abstract principles expressed by mathematical equations. The second one relates to the demonstration of the eddy currents (the exploration demonstration 1 in topic 5, p. 71). In this instance, some students did additional experiments to compare the required minimum alternative voltages supplying for the solenoid to lift the aluminum rings with different sizes. Thus lecture demonstrations created dynamic factors to promote students' creative thinking ability.

How useful the learning cycle was in promoting students' learning science

The first phase of the learning cycle was not only to help students with the identification of the "patterns" of science concepts, but it also provided students with opportunities to expose their prior conceptions to discuss and to modify them. The teacher took advantage of this phase to elicit students' prior knowledge, especially their misconceptions. This factor was very necessary in helping the teacher to construct appropriate lesson plans for lecture sessions.

The exploration phase suggested useful topics for the class discussions in the second phase. These topics emerged from the interaction between students' current ideas and new phenomena. This means that these topics reflected students' needs and concerns. This is one of the essential factors contributing to the construction of an effective science curriculum.

The second phase, together with the introduction of the "terms" representing the "patterns" discovered in the first phase, assisted students to assimilate and accommodate new conceptions, and therefore facilitated their science concept attainment. Learning activities with class discussions in this phase established a less formal atmosphere in the classroom. This situation promoted students to actively share ideas with their peers and their teacher. They felt free to interrupt the discussions to ask for clarification. Therefore, the interaction between the students and the teacher was much greater than that occurring in the traditional lecture classes.

The most obvious difference between teaching physics with the learning cycle and with the traditional models of instruction was the immediate feedback received from students. By the time students returned to the physics lab for the application phase, they had been forced to use the material presented in the previous phase. During this phase, if they had difficulties, they could ask questions, and the group discussions would help them with these. Students usually sought help from their peers. As a result, interaction between students was much greater than in a usual lecture class.

Most students immediately recognized the value of the application phase, after the first learning cycle. However, the exploration activities appeared to be considered less valuable in the early weeks because most students did not know the purpose of this phase. After they completed a few learning cycles, they understood that the exploration phase is to prepare them to learn new concepts or principles. The exploration activities, that seemed frustrating at the beginning of the course, became enjoyable learning experiences at the last half of the course.

Limitations of the study

In this study, the research design, the data analyses, and the students' assessments were limited by the following factors:

- The research results cannot be generalized to a large population because the data were collected from a small sample of students, mostly including average and poor students.
- Students' keeping journals was voluntary, and included fairly good and near average students - the class minority. This might result in a biased database.
- The questionnaire was administered once at the end of the course when the students' interests were reaching the highest level. Some biases cannot be avoided in this context.
- Since the sudden breakdown of the Van De Graaff generator, some electrostatic demonstrations were presented in descriptive form instead of "live" demonstrations. This fact affected students' involvement in the learning activities in the early weeks.

- The assessment of the extent to which students understand physical concepts or law of physics was based mainly on the activity sheets, and partly on the teacher's and students' journals. This resulted in some difficulties in coding the data, and therefore limited the reliability of the findings. Furthermore, most of these assessments were mainly performed on the basis of these findings and the researcher's personal viewpoint. The assessment results might be influenced by the researcher's subjective ideas.
- The data analyses and interpretations were limited by the descriptive manner of the analyses, and general manner of the interpretations. The researcher was unable to go further to lead to a thorough analysis of students' conceptions and abilities. This study failed to go further into students' psychological phenomena.
- Most students had to take from 3 to 4 courses (from 12 to 15 credits) in only 2 months. So the time they devoted for studying physics was limited. Moreover, the textbooks and the teaching materials concerning the physics lectures as well as the physics demonstrations were also restricted. All of these factors partly influenced students' involvement in the learning activities.
- The construction of the midterm tests and the final exam were focused not only on the purpose of the study, but also on the assessment criteria required by the faculty and the academic office to ensure the balance in students' assessment between the experimental class and the other classes receiving the traditional instruction. This situation resulted in the lack of some information necessary for data analyses and

interpretations, especially for the common assessment of students' achievement based on learning objectives in the instructional design.

- The various sources of data collected from the instruments mentioned in Chapter 3 (including students' explanations of physical phenomena, students' statements and ideas in their journals, and so on) were first recorded in Vietnamese, and then were translated into English. Although many efforts were made by the researcher to ensure the accurate reflections of the original information, some deficiencies in the translating process were unavoidable.

Implications

At present, innovations in Vietnamese higher education are in process, especially reforms in science curricula and teaching strategies. The instructional design suggested in this study contributes to the enhancement of the quality of science teaching at the College of General Studies in Ho Chi Minh City. As mentioned earlier in Chapter 3, the CGS is responsible for training first and second-year students at Ho Chi Minh City, and southern provinces. Therefore, the total enrollment has increased significantly, and the science teaching for large-enrollment classes has been encouraged. Since this instructional design is well suited to physics teaching for a large-enrollment class, it can be applied to physics teaching at the CGS. However, for the long-term application of this model, students' activities in the physics lab should be replaced by activities in the open lab environment administered by teaching assistants.

Through pilot teaching with demonstrations using the learning cycle for college students at the CGS, and based on students' needs and concerns, there is evidence to suggest that this curriculum model should be developed not only for the electromagnetic section, but also for other sections of the introductory physics course, if the CGS supports finance and equipment for the establishment of an open lab. With these supports, the feasibility of this design mainly depends on the teachers' choice. If physics teachers have enough enthusiasm, and would like to be genuine teachers, not to be presenters of information or clarifiers of ideas in text books, this instructional design may contribute to physics teaching at the CGS.

Some suggestions need to be paid attention in designing this curricular model:

- Developing physics demonstrations in corporation with the learning cycle to create cognitive conflicts necessary for students' assimilation and accommodation of science knowledge.
- Organizing instruction so that teachers can spend a substantial portion of their time diagnosing students' misconceptions.

The teacher, as presenter or a clarifier, is clearly not adequate for helping students assimilate and accommodate new science knowledge. This study suggests that the teacher should confront students with problems arising from their attempts to help them to assimilate new conceptions in order to facilitate their accommodation.

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Appendix A

Consent from the College of General Studies

VIETNAMESE MINISTRY OF EDUCATION AND TRAINING

NATIONAL UNIVERSITY OF HO CHI MINH CITY

College of General Studies **Thu Duc, Ho Chi Minh City, Vietnam**
Telephone: 011 848 962 820

ACKNOWLEDGMENT LETTER

Simon Fraser University
Burnaby, British Columbia, V5A 1S6
Canada

June 18, 1996

Dear Sir/Madam:

According to the proposed research of Ms. Tran Thi Thien Huong submitted to the College of General Studies on June 18, 1996; the College of General Studies permits Ms. Huong to teach a pilot course of 45 teaching periods on Electricity and Magnetism for the class of about 120 students during the period of July 8 to August 31, 1996. Ms. Huong is also allowed to make her observations, to implement students' journal keeping and questionnaires on students' attitudes toward teaching and learning physics with the combination of physics lectures and demonstrations by using the learning cycles.

The College of General Studies is very pleased to provide her with available facilities to help her to accomplish her research.

Sincerely,

Bui Ngoc Tho

Associate Professor

Rector of the General of General Studies

Appendix B

An introduction letter to students

Welcome all of you who will be taking the physics A2 course in the first phase. This course will provide you with a basic understanding of concepts and fundamental principles of electric and magnetic interaction. Through this course, you will gain an insight into the relationship between fundamental law of physics and simple technological applications. It will be my pleasure to work with you throughout 45 teaching periods of physics to discover a small part of " physics world". You will be shown that physics is a basic and enjoyable science through lecture demonstrations and interesting learning activities. Lecture demonstrations will be implemented with the learning cycle model in which you will have opportunities to explore physical concepts and principles by yourselves before the lectures. Through class discussions, the teacher will guide you to a correct understanding of these concepts and principles. Finally, you will be provided with opportunities to apply what you just learned in a new situation to enhance your understanding.

Learning activities involve reading teaching materials (physics textbooks and laboratory manual for physics demonstrations), group discussions in the physics laboratory, answering questions on the activities sheets, class discussions in the class sessions, doing physics problem in the textbook. With these activities, you will not sit behind the tables to be taught physics but you will be positively engaged in learning physics.

This course requires you to have a mastery of mathematics and physics at the high school level, and skills of calculus and vector calculus at the first semester of the university level. At the end of this course, you will be evaluated on your own level of mastery of the course material.

I am always interested in improving physics curriculum and instructional methods to enhance the quality of physics teaching. What I mentioned above is part of my Master' s thesis on physics education. In order to assess the curricular model I designed, I would like to engage you in my study. Your contributions to the work I am pursuing has great meaning to me. It will be my pleasure to receive your opinions and feedback from your journal keeping, your responses to questionnaires, your participation in lad and class activities.

Information collected from you will be useful for evaluating the effectiveness of this curricular model and the effect of teaching and learning strategies on students' physics learning.

Thank you very much for your participation and your contributions. I hope you enjoy studying physics and get good marks in this course.

Ho Chi Minh City, July 8, 1996

Tran Thi Thien Huong

Appendix C

Topics in the pilot teaching

Week	***Topics in the course***	***Time****	***Topics in physics demonstrations***	***Time*****
1	*Chapter 1*: Electrostatics: Charges, Coulomb's law, electric field	3	*Topic 1*: Electric charge, electrostatic induction, Coulomb's law	2
2	Chapter 1: Gauss's law, electric potential, the relationship between electric field and electric potential	3	*Topic 2*: Electric potential	2
3	*Chapter 2*: Conductors in an electric field	3	*Topic 3*: Conductors in electrostatic equilibrium and its applications	2
4	*Chapter 3*: Dielectric and electrostatic energy	5		
5	*Chapter 4*: Magnetic interaction and magnetic field	5		
6	*Chapter 4*: Gauss's law for magnetic field and Ampere's law	5		
7	*Chapter 5*: Electromagnetic induction	3	*Topic 4*: Electromagnetic induction	2

8	*Chapter 6*: Magnetism in matter	2	*Topic 5*: Eddy current and its technological applications	2
	Chapter 7: Electromagnetic field and wave	2		

Total: 31 45-minute periods Total: 10 hours

Midterm test 1: 2 45-minute periods

Midterm test 2: 2 45-minute periods

Final exam***: 2 hours

The total time for the course: 45 teaching periods

* Including the time for concept introduction phase, the lecture time, and the time for solving physics problems.

** Including the time in the physics lab for exploration and application phases.

*** not including in the course time.

Schedule for the learning cycles

	In the demonstration laboratory	***In the class sessions***
Monday	*Exploration phase* (An hour per week) (Group discussion)	
Wednesday		*Concept introduction* (A 45-minute period per week) (Class discussion) *Other learning activities* (Two 45-minute periods per week)
Friday	*Application phase* (An hour per week) (Group discussion)	

Teaching materials

Textbooks:

Luong, Duyen-Binh., Nguyen, Huu-Ho., & Du, Tri-Cong. (1994). General physics for engineering students. Ha-Noi: Ministry of Education and Training press.

Hoang, Van-Cam. (1991). General physics. Ho Chi Minh: University of technology.

Nguyen, Van- Lai., & Nguyen-Thi, Hong-Hoa. (1993). General physics. Ho Chi Minh: University of technology.

Tran-Thi, Thien-Huong. (1994). Electricity, Magnetism, Oscillations, and Waves. Ho Chi Minh: Pedagogical University of Technology of Ho Chi Minh City.

Laboratory manual for physics demonstrations:

Tran-Thi, Thien-Huong. (1996). Physics demonstrations in Electricity and Magnetism. Unpublished teaching material for physics A2 course. College of General Studies: Faculty of Physics.

Appendix D

Consent by students attending the pilot teaching

Having asked by Ms. Tran Thi Thien Huong of the Education Faculty of Simon Fraser University to participate in the study entitled "A model using learning cycles to combine lectures with demonstrations in physics teaching at the first-two-year university level", we have been informed about the procedures being used in this study.

We understand the purpose of this study is to evaluate the effectiveness of using an instructional model for physics teaching in higher education. We also understand the procedures to be used in this study.

We understand that we may withdraw our participation in this study at any time. We know that we may register any complaint we may have about the study with the chief researcher named above, with Dr. Allan MacKinnon, supervisor - Associate Professor of the Education Faculty (Telephone: 604-291-3432), or Dr. Robin Barrow, Dean of the Education Faculty (Telephone: 604-291-3395), Simon Fraser University (Fax: 604-291-3203).

We may examine the report on the results of this study by contacting Ms. Tran Thi Thien Huong, physics teacher at the Physics Department of the College of General Studies, National University of Ho Chi Minh City. We have been informed that the research material will be held confidential by the principal investigator, Ms. Huong.

We agree to participate in this study by:

- Attending the pilot teaching during the period of July 8 to August 31, 1996 at the Physics Department of the College of General Studies, National University of Ho Chi Minh City.
- Answering the questionnaires on students' opinions about learning physics with lecture demonstrations and learning cycles at the end of the course.

Name	**Address**	**Signature**

Witness: Pham Kim Tuyen, The Vice Director of Physics Department, College of General Studies, National University of Ho Chi Minh City.

Date: July 8,1996

Appendix E

Consent by students for participating in journal keeping

Having asked by Ms. Tran Thi Thien Huong of the Education Faculty of Simon Fraser University to participate in the study entitled "A model using learning cycles to combine lectures with demonstrations in physics teaching at the first-two-year university level", we have been informed about the procedures being used in this study.

We understand the purpose of this study is to evaluate the effectiveness of using an instructional model for physics teaching in higher education. We also understand the procedures to be used in this study.

We understand that we may withdraw our participation in this study at any time. We know that we may register any complaint we may have about the study with the chief researcher named above, with Dr. Allan MacKinnon, supervisor - Associate Professor of the Education Faculty (Telephone: 604-291-3432), or Dr. Robin Barrow (Telephone: 604 291-3395), Dean of the Education Faculty, Simon Fraser University (Fax 604-291-3203).

We may examine the report on the results of this study by contacting Ms. Tran Thi Thien Huong, physics teacher at the Physics Department of the College of General Studies, National University of Ho Chi Minh City. We have been informed that the research material will be held confidential by the principal investigator, Ms. Huong.

We agree to participate by keeping journals after each phase of the learning cycles in every topic during the period of July 8 to August 31, 1996 at the Physics Department of the College of General Studies, National University of Ho Chi Minh City. We are ensured that our ideas and comments will not in anyway influence our progress in the physics course. We also know that we will be paid for our efforts.

Name	Address	Signature
1) Le Thanh Phong	72B Gian dan Hamlet, Long Thanh My Village, Thu Duc District, Ho Chi Minh City.	
2) Ly Trung Cang	50/69 Hamlet 5, Tan Qui Dong Village, Nha Be District, Ho Chi Minh City.	
3) Hoang Trung Chinh	131 Thong Nhat Street, Thu Duc District, Ho Chi Minh City.	
4) Vo Dinh Duong	217A Tan Phu Dormitory, Thu Duc District, Ho Chi Minh City.	
5) Tran Duc Huy	123A Tan Phu Dormitory, Thu Duc District, Ho Chi Minh City.	
6) Pham Quoc Viet	170 Nam Ky Khoi Nghia Street, District 3, Ho Chi Minh City.	
7) Duong Hong Phi Vu	39/2 Truong Tre Hamlet, Linh Xuan Village, Thu Duc District, Ho Chi Minh City.	
8) Nguyen Thanh Hai	Thanh Phu Hamlet, Tang Nhon Phu Village, Thu Duc District, Ho Chi Minh City.	
9) Nguyen Phuoc Hau	311A Tan Phu Dormitory, Thu Duc District, Ho Chi Minh City.	
10) Nguyen Kim Huy	64/5 Tan Mai Quarter, Bien Hoa City.	
11) Pham Thanh Thiet	6 Yen The Street, Quarter 10, Da Lat City.	
12) Tran Anh Tuan	137/42 Ben Van Don, Quarter 6, District 4, Ho Chi Minh City.	

Witness: Pham Kim Tuyen, The Vice Director of Physics Department, College of General Studies, National University of Ho Chi Minh City.

Date: July 8,1996

Appendix F

Questionnaire on students' attitudes toward physics

Please answer every statement below by cycling the appropriate number to show how far you agree or disagree with each statement.

SA means "strongly agree"
A means "agree"
U means "undecided"
D means "strongly disagree"
SD means "disagree"

Enjoyment of physics

1) I feel interested in learning physics. SA A U D SD

2) Physics is not an interesting course SA A U D SD

3) I enjoy studying physics with demonstration experiments SA A U D SD

4) I fear to study physics with demonstration experiments SA A U D SD

5) I would like to do demonstration experiments related to technological applications. SA A U D SD

6) I would like to spend more time in studying physics SA A U D SD

7) I feel interested in learning activities in the demonstration laboratory. SA A U D SD

8) I would like to spend less time in the physics laboratory doing demonstrations.

Motivation in physics

9) I think I need to study physics. SA A U D SD

10) I am taking physics course because I want to complete my undergraduate degree. SA A U D SD

11) Demonstration experiments help me more clearly understand physics lectures. SA A U D SD

12) It is hard for me to comprehend physical concepts and principles SA A U D SD

13) Physics with demonstration experiments involve interesting and funny things. SA A U D SD

14) Demonstration experiments motivate my curiosity, and force me to think more about the lectures. SA A U D SD

Value of physics course for student's career and life

15) I found nothing useful when studying physics. SA A U D SD

16) Physics is very necessary for my future career. SA A U D SD

17) Technological issues are closely related to knowledge of physics. SA A U D SD

18) I think I can apply knowledge of physics to my work after graduation. SA A U D SD

19) Engineering students must have basic understanding of physics. SA A U D SD

20) Only physicists or physics teachers need to have knowledge of physics. SA A U D SD

Appendix G

Guidelines for student's journal keeping

You volunteered for keeping journals to support more information for my study. At first, I think I should let you know why I asked you to keep journals. In my study, I attempt to evaluate the effectiveness of the curricular model I designed for the second physics course at the College of General Studies of the National University of Ho Chi Minh City. Therefore, I would like to know your understanding of the course through your thinking and feelings. I am very please to listen you expressing your subjective reactions to various aspects of the course. Your descriptions will help me to have an insight into your understanding of the course and your responses to the study. You will be asked to keep journals after every phase of the learning cycles in every topic. You should focus on the following aspects:

- Your background in math and physics related to every topic.
- What you understand the topic (concepts or principles involved in the topic).
- How you understand the topic (by reading the textbook, the laboratory manual for physics demonstrations, or other materials, through group discussions, class discussions, or from talking to your friends).
- What activities seemed most and least effective at promoting your learning
- Which activities you enjoyed most and which you enjoyed least.
- How much time you spent on various activities.

At the first time you keep journal, please tell me what you think about studying physics in high school and your career aspirations.

You are reminded that you are free to write down what you really think. You are encouraged to express your own opinions. You can exchange your ideas with you friends to provide me with more information. You are ensured that your ideas will not anyway influence your progress in the physics course. You will be paid for your efforts.

Thank you very much for your co-operation.

Appendix H

Guidelines for teacher's journal keeping

The following questions was structured as a framework for teacher's journal keeping.

In the first of the class:

- How do students react when being informed of the intended learning activities?

In the exploration phase:

- Do students hesitate or feel free to attend the lab activities before the lecture?
- Are they interested in physics demonstrations?
- Do the demonstrations stimulate their curiosity?
- Are the group discussions effective, exciting, and enthusiastic?
- Do they feel easy or difficult to answer the questions on the activities sheets?

In the concept introduction phase:

- How do the teacher guide the learning activities in this phase?
- Do students recognize physical concepts or principles by themselves or with the help of the teacher?
- How are the class discussions? (effective, exciting, and enthusiastic).
- How do students listen to the teacher and their peers? How do they share their ideas?
- How do they get involved in the class discussion?

In the application phase:

- Are they interested in learning activities in this phase?

- Are they able to apply the concepts or principles they have just learn to new situations?
- How are the group discussions?
- Do they feel easy or difficult to answer the questions on the activities sheets?

In the last day of the class

- How do students react in the last day of the class?