APPLYING PROBLEM-SOLVING APPROACHES IN A GENERAL PHYSICS LABORATORY
In The College Of Natural Sciences, Ho Chi Minh City, Vietnam

by

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Abstract

Most science educators agree that the laboratory is an integral and necessary aspect of the learning experience in science courses. However, many researchers suggest that the potential of the laboratory to enhance learning depends on teacher attitudes, student behaviors, and management and organization of the program of studies, among other things. In Vietnam, most students are quite "passive" in their study; even in the teaching laboratory, there is a tendency for students to be told what to do, how to do it, what they should find, and what it means. There is little opportunity for students to "think for themselves," or to experience science as a process of experimentation and analysis. This study examines a problem-solving approach for a general physics laboratory in the College of Natural Sciences, Vietnam National University-Ho Chi Minh City.

This thesis is a descriptive study of one laboratory experiment and students' problem-solving skills in such an environment. An interpretive research methodology was adopted for analyzing the data. The data sources include videotapes, their transcripts, student laboratory reports, a questionnaire used to measure students' attitudes to laboratory work, and the opinion of the students and the teacher who participated in this study. Six students who were in their first year of university study and a teacher with eight years of teaching experience in the physics teaching laboratory participated in this study.

This study focuses on the interactions between students and their peers, as well as

between students and the teacher. In particular, the study focuses on the way students understand the problem, and their independent and collaborative efforts in developing their investigations. Of particular interest was students' abilities to design strategies to solve the problem without referring to a "cook-book." This study also shows the complexities of laboratory learning, particularly in terms of the students' background knowledge and experience as key elements of their ability to make meaning. Finally, the problem-solving approach used in the laboratory provides opportunities for students to develop and practice their skills in scientific investigation. This study is an important part of the effort to improve the quality of science education in Vietnam.

Dedication

For my parents

Acknowledgments

I would like to express my sincere thanks and appreciation to my supervisor, Dr. Allan MacKinnon. Thank you for all you have done for me, for your generosity and encouragement in my work.

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Chapter I

Introduction

In recent years, since the establishment of the "open door policy" of the Vietnamese government, there has been rapid economic growth in Vietnam. There has been much support from the developed countries and remarkable efforts to upgrade education in the country.

In 1996, the Vietnam National University was founded, with two large campuses--one in Ho Chi Minh City and one in Hanoi. The Campus in Ho Chi Minh City currently comprises eight Colleges in the following areas of study: Natural Science, Social Science and Humanities, Technology, Economics, Agriculture, Education, Technology Education, and Trade. The College of Natural Sciences consists of seven departments of science and one research center (funded by the World Bank) with modern instruments. This is one of the most modern research centers in South Vietnam. The main tasks of the departments are education and research in their respective disciplines. The College of Natural Science offers Bachelor's, Master's and Doctorate degrees in the natural sciences, as well as special short-term graduate and post-graduate courses. Under the direct management of the College of Natural Sciences, there is a special secondary school for pupils gifted in mathematics, informatics, physics, and chemistry. The Bachelor's degree consists of four years of study divided into two phases of two years each. In the first phase of the undergraduate program, the students study basic subjects of each training field, after which they choose a narrow specialization in the second phase. The Master's program has a duration of three years and the Doctorate degrees, three years (if transferred from the Masters program) or five years (if transferred from Bachelor's level).

Background to the problem

At the national conference of Rectors and Directors of universities and colleges in Hanoi, Vietnam, February 1998, Party General Secretary Le Kha Phieu emphasized the need for better care to be taken in higher education. Industrialization and modernization have required workers to have a standardized education. He noted that trained labour must meet the requirements of modernization and is not as easily available as was the type of manual labour we had previously.

At that National Conference, many educators in Vietnam expressed dissatisfaction with the state of science education in the Universities. The following summary of their conclusions identifies the elements of this crisis.

- Students' knowledge of basic science is very low and lacking in modernization.
- Most students do not enjoy science and do not see the value of science in their daily lives.
- Students are passive in their learning. They only take notes of their teachers' lectures.
- Much of this results from the low capabilities of teachers and related lack of textbooks and teaching material.
- Laboratories and workshops at many science colleges and technical schools are poor and antiquated.

Much of the dissatistation with higher education in Vietnam has to do with the heavy reliance on rote learning.

According to Lord (1994), "Knowledge can not simply be transferred from the book or video tape or the mouth of the teacher into the heads of the learners" (p. 346). He suggests that:

> Students need to be actively thinking about what is being presented if they are to retain the information. They need to be alert and involved and to expend energy in the cognitive process. Knowledge is gained by students when the information they encounter interacts with their existing perceptions. (p. 346)

If one accepts this notion of how a student learns, he or she will appreciate the view of learning called constructivist theory. Constructivist theory has become very widespread in the fields of education, epistemology, history and philosophy of science, cognitive and social psychology, philosophy, and the sociology of science (Bruner, 1986; Gergen, 1985; Von Glasersfeld, 1987). Hodson (1996) states that:

> During the 1980s and early 1990s, constructivist approaches to learning science have become increasing prominent as teachers and curriculum developers have sought to locate learning in the personal understanding and experience of individual learners. (p. 115)

Certainly, constructivist ideas could prove to be useful in Vietnamese universities.

I have taught for many years in a general physics laboratory at the College of Natural Science (this was the Physics Department of the University of Ho Chi Minh City before the National University was founded). I have always been concerned with helping students to understand the nature of science and providing experiences in scientific inquiry. Most science educators agree that the laboratory is an integral and necessary aspect of the learning experience in science. However, some of the students in mathematics, informatics and biology have told me, over the years, that they think their field of study is not related to physics, and, therefore, that they did not need to study in the general physics laboratory.

At the end of the semester when students have final exams many of them complain to me that there are too many things to remember and, therefore, they have low achievement.

I have recognized many problems in the general physics laboratory, but I believe there are two primary problems. First, students in the high school were taught physics completely by the lecture approach. When they begin their university study, the majority of science students have never experienced a laboratory-based, investigative approach. Second, in the general physics laboratory, experimental tasks often embody a "cookbook approach" in which students "follow recipes" in gathering and recording data, without a clear sense of purposes, procedures or the significance of their findings. Therefore, students will forget rapidly.

Pushkin (1997) stated that:

> When the students are regimented by laboratory manuals that dictate what to think, how to think, when to think, laboratory activities essentially lose impact for learning. (p. 178)

In order to improve the effectiveness of laboratory instruction I hope to apply a constructivist approach in the general physics laboratory. Ritchie and Rigano (1996) stated that:

> A common response to the constructivism reform movement is to replace "cookbook" (or recipe) laboratory activities (or practical) with open-ended inquiry. Such inquiry typically follows on from personally framed investigable questions. (p. 800)

Purpose of the study

This thesis examines the application of a constructivist approach in the general physics laboratory for first-year basic science students at the College of Natural Sciences. Specifically, this work investigates one laboratory that was designed to engage students less in simply following directions, and more in genuine science inquiry.

The study took place in the context of a general physics teaching laboratory that is associated with an introductory course in basic physics. In the traditional general physics teaching laboratory, a set of activites are undertaken by students in a "cookbook" style, in which they are given tasks and a set of procedures to follow in carrying out the tasks. Students frequently follow the "recipe," with little understanding of what they are doing and why, the purpose of the activity, and its significance in terms of their learning of physics (i.e., demonstration and illustration of theoretical principles developed in the lecture course). This study attempted to assist students in understanding problems and procedures more thoroughly, to enable them to develop their own unique perspective and protocol for an investigation, develop the skill of problem solving, and understand more of the process of doing science. Two activities were developed as modifications of the traditional activities included in the electronics unit of the teaching laboratory—one pertaining to the meter, the other pertaining to the diode. Pre-lab questions were developed to assist students in preparing for the problem-solving activities during the investigations and an explicit attempt was made to encourage them to develop their procedures on their own, with occasional reference the "cookbook," which they had read in advance of the laboratory session.

The second part of the study documents and analyses students'work during the laboratory exercises. A case study is developed to document the nature of students' learning in the laboratory. Students' understanding of laboratory work will be examined in terms of their hypotheses during the laboratory investigations, their development of a plan for their investigation, how they carry out their plan and collect data, their analysis of data and attitudes toward laboratory work. Specifically, I am interested in finding answers to questions such as:

How do students working in the groups understand the problem of the laboratory activity?

How do students design strategies for solving the problem?

How do students implement a plan to collect and analyze data to answer the problem?

The advantages and limitations of this design will also be discussed in order to draw reasonable conclusions and implications for the use of constructivist approaches in the present conditions in Vietnam.

Significance of the study

It is hoped that this study brings a useful innovation to university teaching in Vietnam. The study should help inform physics teachers about how to improve laboratory instruction, increasing the value and quality of the laboratory in science education. This study is seen as an important part of the effort to improve the quality of education in Vietnam.

Chapter II

Review of Related Literature

A "Project 2061" report (AAAS, 1989) on literacy goals in science, mathematics and technology in the USA states that:

> The present science textbooks and methods of instruction, often actually impede progress toward scientific literacy. They emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, recitation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities. (p. 14)

It is apparent that students are often in full command of science terminology and, for example, might be able to write down the Schroedinger equation without any difficulties. However, there often is no deep understanding. How can teaching help students to develop deep understanding of the nature of science and gain experience in scientific inquiry?

Constructivism is a contemporary philosophical viewpoint that can be applied to the teaching and learning of science. In the first section of this chapter I describe the nature of constructivism, and the constructivist view of teaching and learning science. In the second section the role of experiment in learning science is discussed and implications of the constructivist perspective for the laboratory are presented.

The nature of constructivism

Von Glasersfeld (1992) notes that:

> From the beginning of the 5th Century B.C., the skeptics have shown that it is logically impossible to establish the "truth" of any particular piece of knowledge. The necessary comparison of the piece of knowledge with the "reality" it is supposed to represent can not be made, because the only rational access to that reality is through yet another act of knowing. (p. 5)

Skeptics of the realist perspective remind us that it is impossible to judge how well our mental images correspond to reality because the only way we can perceive reality is through these images. But if our strategies for determining truth rely solely on the "correspondence" between knowledge claims and reality, we are left with an impoverished view of science. Surely, scientific knowledge depends also on pragmatic and coherence truth strategies. A more useful discussion might call into question what is meant by a scientific "fact" and draw attention to how scientific observations can be "theory-laden." Goldstein and Goldstein (1978), for example, recognize that:

> There is a difference between the commonsense view of "facts" as hard, inescapable, unchangeable things and the reality in science where the things we call facts are fuzzier. Facts have a culturally conditioned component and are partly created by the theories we hold, and thus one subject to change if the theories themselves are changed. (p. 18)

An example in twentieth century physics illustrates these ideas. In 1913, Niels Bohr proposed a visual model to represents the hydrogen atom as a planetary system in which the proton is 10^{-11} cm in diameter and 1,840 times as heavy as the electron. The distance between the two is approximately 5×10^{-9} cm with the electron acting like a large but incredibly swift cloud, revolving about the proton about 10^{16} times per second. This model accounted with amazing success for the light emitted by the hydrogen atom. The electron's motion produced a sort of "harmony of the spheres" which became visible in its spectrum. However, experiments have shown that there was a kind of light, which the electron could reflect, and it was supposed that the reflected light came from a definite point on its orbit. From Bohr's theory, which claimed the existence of these orbits, it followed that a certain time is required for any signal to be reflected. In this instance that time is about 10^{-10} seconds: the electron needs at least that much time to interact with a light wave. This means that the light wave would indicate where the electron was, but the number of orbits described in 1 second is, according to Bohr' s theory, about 10^{16}. Hence in that minuscule interval the electron would have revolved many million times. Clearly there is something wrong with the theory. Many difficulties of this sort arose in connection with the Bohr model, and the theoretical physicists of the 1930s and 1940s had difficulty using the Bohr model to picture the atom in terms of visible things. The scientists constructed a model of the electron that was viable in its representation and explanation of observed data at that period in time. But no matter how elegant, that model can not claim absolute truth.

According to Tobin (1993), "A constructivist perspective acknowledges the existence of an external reality but realizes that cognizant beings can never know what that reality is actually like" (p. 4). He points out that "Constructivism is not concerned with the question of knowledge as a representation of truth; rather, it focuses on the manner in which knowers construct viable knowledge" (p. 4).

Von Glasersfeld (1992) states that:

> Viability--quite unlike "truth"--is relative to a context of goals and purposes. But these goals and purposes are not limited to the concrete or material. In science, for instance, there is, beyond the goal of solving specific problems, the goal of constructing as coherent a model of the experiential world as possible. (p. 7)

Knowledge enables an individual to pursue goals in the multiple contexts in which actions occur. Knowledge must be viable not only personally, but also in the social contexts in which actions are to occur (Tobin, 1993).

The constructivist perspective on learning and teaching science

As noted earlier, constructivism is a contemporary philosophical viewpoint that can be applied to the teaching and learning of science. From a constructivist perspective, then, science is not the search for truth, but a process that helps make sense of the world (Wildy & Wallace, 1995, p. 145). According to Von Glasersfeld (1987) a constructivist perspective can be summarized by two main principles.

The first principle is that knowledge is not passively received but actively built up by the learner not by passive reception from a teacher, but by an active and vivid interplay between the learner's existing understanding and current experiences. The second principle of the constructivist perspective states that the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. Different interpretations of events may occur because of differences in background, culture, interests, education, and priorities in life. In other words, a particular event may carry a different meaning for one person than it does for another (MacKinnon, 1990, p. 4). From these principles of constructivism, MacKinnon (1990) has commented on the matter of science teaching as follows:

> (1) Teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts; (2) These ideas must then be taken into account in the instructional program in order to provide a foundation for extending concepts, or constructing new concepts and the meaning derived from them; and (3) As learning is seen to be a purposive activity, students should be actively engaged in the learning situation and should become aware of the purposes that lie behind instruction. (p. 24)

If learning is not a purposive activity, students will not know where to look, or how to look, in order to make observations appropriate to the task at hand or how to interpret what they see. Gunstone, Richard, Fensham and Baird (1991) stated that:

> When learners have a different theoretical framework from that assumed by the teacher, they may look in a different (wrong?) place, with different wrong interpretations, sometimes even vehemently denying observational evidence that conflicts with their existing views. (p. 182)

According to Piaget's theory, the learning process consists of a continuous sequence of small steps. Each step is initiated when the individual encounters an object or idea that is not familiar and thus can not be fit into her or his mental framework. This encounter engenders confusion, called "disequilibration" or "cognitive conflict." The learner then begins to manipulate the new object or idea and works through a process termed "equilibration" or self-regulation to modify her/ his mental structure to accommodate the new unfamiliar phenomenon. Saunders (1992) develops a constructivist learning model of the interaction between the learner and the environment. Figure 1 shows the connections between the learner's cognitive universe (internal) and the physical universe (external).

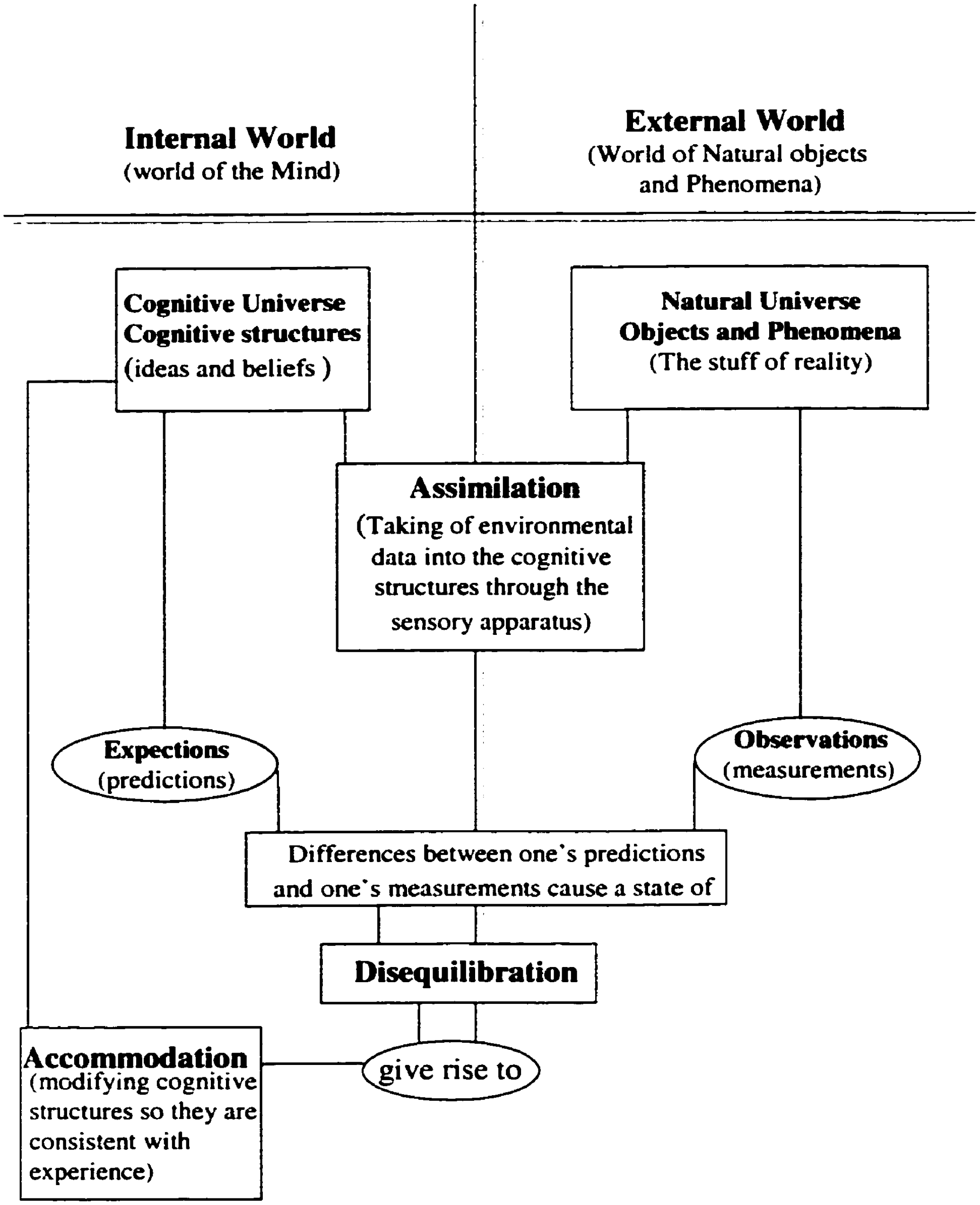


Figure 1: Saunder's model of cognition

When the learner's expectations (predictions) do not coincide with experience (measurement) the result is disequilibration. Disequilibration can result in the modification of one's schema, that is, the learner restructures his or her schema such that expectations are more in agreement with one's experience. This schema restructuring process is interpreted as meaningful learning. Learners construct knowledge through a psychologically active process in which knowledge structures are sometimes highly resistant to change. Disequilibrating experiences can result in modification of these cognitive structures and hence give rise to increases in learners' understanding of the world (Saunders, 1992). Equilibration is the regulatory process by means of which assimilation and accommodation are kept pace. According to Piaget, the actual changes in thinking take place through the process of equilibration. Piaget assumed that people continually test the adequacy of their thinking processes in order to achieve that balance. If we apply a particular scheme to an event or situation and the scheme works, then equilibrium exists. Woolfolk (1995) states that:

> If the scheme does not produce a satisfying result, then disequilibrium exists, and we become uncomfortable. This motivates us to keep searching for a solution through assimilation and accommodation, and thus our thinking changes and moves ahead. In order to maintain a balance between our schemes for understanding the world and the data the world provides, we continually assimilate new information using existing schemes, and we accommodate our thinking whenever unsuccessful attempts to assimilate produce disequilibrium. (p. 32)

It is plausible that learning occurs as students try to make sense of what is taught by trying to fit new ideas with their own experience. In the context of the classroom, two central premises of the constructivist perspective are (1) knowledge is constructed in the mind of the learner (2) on the basis of pre-existing cognitive structures or schemes. Thus a constructivist account of learning is concerned with the "intents, beliefs and emotions of individuals as well as their conceptualizations, and recognizes the influence that prior experience has on the way phenomena are perceived and interpreted" (Driver & Oldham, 1986, p. 106).

Saunders (1992) suggested that:

> The teacher can not modify the student's cognitive structure, only the student can. The teacher can assist students with cognitive restructuring by placing them in situations which result in disequilibration. The teacher can not convey or transmit meaning. The teacher can only transmit words. Meaning must be created by the student. (p. 137)

A constructivist perspective has important consequences for the role of the teacher in a classroom. Yager (1996) stated that:

> The teacher is viewed as a facilitator of knowledge construction (that is, as a guide in students' individual construction processes) rather than as a person who transfers knowledge to the brains of the students. Teachers and students are seen as partners in the teaching and learning situation. Consequently, students are given more command of their own learning and more responsibility for it. Relations between students and teachers are more symmetrical than in teacher-dominated classrooms. (p. 52)

The teacher's role is to monitor student understandings and guide discussions so that all students have opportunities to put language to their experiences and to engage in activities, justifying, and evaluating alternative points of view (Tobin, 1993). From a constructivist perspective, Hodson (1996) suggested four main steps for the teacher:

- Identify students' ideas and views.
- Create opportunities for students to explore their ideas and test their robustness in explaining phenomena, accounting for events and making predictions.
- Provide stimuli for students to develop, modify and where necessary change their ideas and views.
- Support their attempts to re-think and reconstruct their ideas and views. (p. 127)

The role of experiment in learning science

Hodson (1993) advocated that teachers should accept a mentoring role in students' laboratory learning. He asserted that "the only effective way to learn to do science is by doing science" (p. 128). In the laboratory a problem may be given for which the students have not yet learned a method of solution, or a situation can be created in which a problem exists but has yet to be identified by the student. These are situations in which students can be encouraged to develop skills considered to be creative and orginal. (Hofstein & Lunetta, 1982, p. 207).

The prototype for the modes of inquiry for Grades 9-12 in the National Science Education Standards (NCSESA, 1993) supports the view that laboratories should promote scientific thinking so that a student can engage in science as the scientist does.

> Inquiry in the classroom is a means of promoting and students' curiosity and questioning spirit. Inquiry is a critical component of the science curriculum at all grade levels and in every domain of science. It serves four essential functions:

- To assist in the development of an understanding of scientific concepts.
- To develop an understanding of the nature of scientific inquiry.
- To develop the skills and the disposition to use them-necessary to become independent inquirers about the natural world.
- As a model of how we know what we know in science. (p. 55)

Many science educators agree that experiments play a key role in teaching and learning science in traditional and constructivist settings. However, within the constructivist perspective the role of experiments in the learning process is viewed with more caution than in traditional approaches. In the traditional approach Germann, Haskins and Auls (1996) indicated that:

> These studies report that in general, laboratories are highly structured in that they provide step-by-step detailed instructions. They usually ask students to manipulate materials, make observations and measurements, record results, make qualitative and quantitative relationships, draw conclusions, make inferences and generalizations, and communicate and interpret the results. These manuals, however, did not provide opportunities for students to pose a question to be investigated, formulate a hypothesis to be tested, or predict experimental results; to design observations, measurements, and experimental procedures; to work according to their own design; or to formulate new questions or apply an experimental technique based on the investigation they performed. (p. 482)

Therefore, in the traditional approach, some of the cognitive work has been done for the student instead of by the student (Saunders, 1992, p. 138).

The effects of a constructivist approach in laboratory activities

Problem solving

A study was conducted by Roth (1994) to investigate whether and how students in a constructivist laboratory environment (a) frame questions for laboratory inquiry and design strategies for finding answers, (b) implement their plans to collect data, and (c) analyze the data to answer their initial question and construct new knowledge. Forty-six students from three sections of an introductory physics course for high school juniors participated in this study. The central finding of this study claimed that problem solving in a constructivist approach is more akin to everyday out-of-school contexts than to a traditional teaching approach. He suggested that "there is evidence that the kinds of problem solving skills students learn in school do not transfer to those in out-of-school life" (p. 200). He concluded that "as students pursue these questions of their own interest, they not only learn to gain pleasure from inquiry, they also gain ownership over problems and solutions" (p. 216). He indicated that:

> Framing problems is an important skill in everyday environments, where problems often are undefined or ill-defined, in contrast to textbook problems students encounter in schools, which are well defined and of extremely limited context. This skill is so important that Schön (1983) considers it central for effective problem solving. (p. 216)

Gallet (1998) conducted a study to compare a "cookbook-formula" with a problem-solving laboratory. The research involved two first-year classes and one second-year class in a chemistry teaching laboratory. The result of the data analyses showed that:

> Problems should be structured so as to present a "puzzle," not an illustration of what students already know; it should include topics for which current knowledge is incomplete. Students should be required to prepare a plan in advance for how to proceed, rather than using manuals and written instructions in laboratory work. They should be required to write reports using a very flexible format. Only with discussions, interpretations, inferences, and conclusions do experiments play a meaningful role in learning. With problem solving teaching, the laboratory can be used to identify students' preconceptions and to extend or modify such conceptions. (p. 77)

Blind alleys

Roth (1994) investigated cases in which students framed research questions and planned experiments in which they did not observe the expected effect. He termed these situations "blind alleys."

He noted that many students investigated "blind alleys," and commented:

> The experience of blind alleys would help students in constructing an understanding of the nature of scientific inquiry that is close to the description provided by scientists and sociologists of science alike. (p. 210)

Ritchie and Rigano (1996) conducted a study to describe the work done by students in an undergraduate chemistry laboratory from a constructivist perspective. The research involved two students in high school (years 11 and 12) in an interpretive study of how the students dealt with their daily frustrations and compared their observed practices with descriptions of undesirable school practices. The authors also used the term "blind alleys." They indicated that:

> Hopefully, what they got out of that was that you don't have to get the right answer or wrong answer in research. You get an answer which might agree with what you believe happens. But then if doesn't agree you sort of change the theory to fit the experiment. You don't change the experiment to fit the theory. (p. 810)

Ritchie and Rigano (1996) concluded that "This was an important realization for the students on their way to becoming independent researchers" (p. 810).

Roth (1995) stated that:

> Regular experience and discussion of blind alleys would also help students in developing an understanding and appreciation of

> the nature of scientific inquiry as a tentative enterprise continuously under construction. Such use of blind alleys could counteract the students' tendency to think of the scientific enterprise and its products as rigid and absolute. (p. 125)

It is plausible that from a constructivist perspective, such problematic situations provide favorable conditions for learning, because the problem solver is facing conditions for which no known procedures are available (Wheatley, 1991). Such problem solving in ill-structured domains (from a student's perspective) may lead to blind alleys, unexpected results that constitute insurmountable barriers to finding answers for research questions (Roth, 1994).

Conceptual understanding

A study was conducted by Fischer, Aufschnaiter, and Von Stefan (1993) which investigated constructivist theory in the planning and performance of a unit on "electrostatics" and the analysis of students' learning in terms of the development of the complexity of their cognitive skills. They suggested that:

> (1) Words for new objects, properties etc., are used only when a corresponding meaning is constructed.
>
> (2) The meaning of words changes during the learning process. (p. 165)

Roth (1994) investigated discussions and "negotiations" in student learning. He recognized that, "Students learned to incorporate different viewpoints into their own understanding, to elaborate their own understanding because they had to defend their own ideas, or to compare each other's explanations to produce a better report" (p. 214).

From the laboratory reports students submitted, Roth (1994) points out that "Students were concerned not only for the meaning of the actual data, but also for understanding the transformation to which they submitted these data" (p. 214).

Ritchie and Rigano (1996) conducted research on how students develop their laboratory techniques and conceptual understanding. They suggested that:

> There seemed to be too many new pieces of apparatus, techniques and information for the students to grasp the concepts involved from beginning of the project. As the students became more competent with the laboratory procedures, their understanding accelerated. (p. 805)

Independent research

Although there are differences in relative conceptual backgrounds among students, they bring to their work a stock of embodied laboratory practices. However, Roth (1994) found value in comparing students' work with that of scientists, particularly pointing out similarities between the two.

Ritchie and Rigano (1996) commented on how the students in their study developed as independent researchers. They suggested that:

> The students did not learn the lab techniques by observing their supervisor at work for lengthy periods, followed by a gradual increase in supervised participation. Instead, the students were afforded greater autonomy. They, rather than their supervisor, maintained control of the project. While their supervisor's input was required at the beginning, the students determined how much additional input from the supervisor they required. This model of participation was consistent with the supervisor's perceived role and enabled the students to exercise greater control and owership over their actions than is evident from descriptions of traditional apprenticeship models. (p. 811)

The nature of student-student interactions and the peer group-teacher interaction

Ritchie and Rigino (1996) also commented the student-student relationship, the result of the data analyses shown that negotiated styles of working have been linked to higher motivational levels. Roth conducted two studies (1990, 1996) to investigate interaction among students and interaction between student groups and teachers using a constructivist approach in the physics laboratory.

Roth (1996) paid attention to teacher-student interactions in the laboratory. He suggested that:

> First, teachers need to monitor the participation of group members during the discussions and encourage each individual to contribute to the generation of ideas and interpretations. Second, a brainstorming session at the beginning of a new experiment may help to engender new ideas in less creative students. Third, each student can be assigned the task of generating at least one focus question before coming to the planning session for a new experiment. Fourth, teachers need to foster the establishment of norms which ask students to demand of each other elaboration, justification and backing of individuals ideas. In order to help students develop these skills, teachers may need to model such practice during large group as well as small group interactions. (p. 442)

Summary

The review of related literature has shown strong support for applying constructivist thinking and approaches in the general physics teaching laboratory in Western contexts. It is felt that constructivist thinking and approaches could prove to be effective in Vietnam universities as well.

The research studies have often compared one method of the traditional laboratory with a constructivist laboratory. It is possible that if differences in learning actually did occur between these two methods, but differences may have been masked by confounding variables, by insensitive instrumentation, or by poor experimental design. It is valuable to maintain a critical stance as one investigates new teaching approaches in the general physics laboratory.

Chapter III

Design of The Study

General Goals

This study investigated an approach in the teaching laboratory course designed to improve the learning of science among university physics students. It is hoped the students will begin to understand the process of scientific investigation and the nature of quality laboratory learning at the College of Natural Science. The students attending this course should develop problem-solving skills, reducing the "cookbook" quality of laboratory investigations.

Selection of students

Six students were selected and invited to participate in the study. How were these students selected? First, I sought from the office of the Faculty of General Education of the College of Natural Science a list of about 300 first-year basic science students. 11 female and 20 male students representing "high" to average groups were given a questionnaire (see Appendix E). Of the 31 students selected, 20 returned the questionnaire. This questionnaire included questions to determine students' achievement in high school and their mark on the university entrance examination. From data collected through the questionnaire, I selected six of the highest achieving students (three females and three males) and invited them to participate in the study. I chose six students because I decided to observe two groups of three students during the two laboratory activities. I chose to use groups of three students for the laboratory activities because I was interested in their discussion and interaction with respect to making sense of the procedures they would follow. I didn't want the groups to get too large (four or five students) because that would limit the opportunity for each student to observe the phenomena of interest (the apparatus was too small to be clearly observed by a larger group). I chose two groups because I wanted to focus on the two laboratory activities (meter and diode) in succession according to the schedule presented below.

The students were informed of the nature and purpose of the study. They were given consent forms before participating in the experiment. They understood that they could withdraw their participation in the study at any time, and that their participation was completely voluntary.

The following is a description of the students who participated in the experiment, including their marks in three subjects (Mathematics, Physics, Chemistry) of the College of Natural Science entrance examination. I have used pseudonyms in this document.

The first student: Nguyen Doan Sau (Male)

- Mathematics: 7.5 Physics: 10 Chemistry: 8.5

The second student: Nguyen Thanh Cong (Male)

- Mathematics: 8 Physics: 8 Chemistry: 8

The third student: Vo Phi Cuong (Male)

- Mathematics: 7.5 Physics: 7 Chemistry: 9

The fourth student: Pham Thi Thanh Ha (Female)

- Mathematics: 6.5 Physics: 8.5 Chemistry: 7.5

The fifth student: Dang Vo Ai Loan (Female)

- Mathematics: 6.5 Physics: 7.5 Chemistry: 7.0

The sixth student: Dinh Thi Thuy Linh (Female)

- Mathematics: 7.5 Physics: 6.5 Chemistry: 6.5

All of the students had just finished high school, and were in their first year of University. None of the participants had taken a laboratory course in physics in high school.

Setting up and carrying out the experiment

The study was conducted in a teaching unit which took place during four weeks. The syllabus of the course was the same for all 300 students enrolled in the traditional general physics laboratory (one three-hour session per week is held for 60 students at a time, with four laboratory instructors present to assist them). The six students who participated in this study, therefore, were accountable for the two laboratory activities in the same way as the other students enrolled in the course. The difference in their experience in the laboratory consisted in the pedagogical approach taken in the written materials and in the role of the teacher, as will be discussed below.

In the first week, the students learned error analysis, accuracy and precision. The same approach was used for all 300 students. In the second week the six participating students were divided into two groups of three, one that would work on the meter activity while the other group worked on the diode activity. The students could choose partners with whom they felt comfortable working. Group one included Sau, Ha, and Loan; Group two included Cong, Cuong, and Linh. In the third week, group one and two switched activities. During the last week, the students took a mid-term examination.

The content of the laboratory course is based on the syllabus of the curriculum for first-year basic science students. After week two, the activity of the diode session was limited by the equipment and the content. Therefore, the study only focussed on the meter session (using a galvanometer as an ammeter or voltmeter see Appendix A).

Laboratory session	Group 1	Group 2
Week 2	Diode	Meter
Week 3	Meter	Diode

Table 1: Schedule for laboratory session

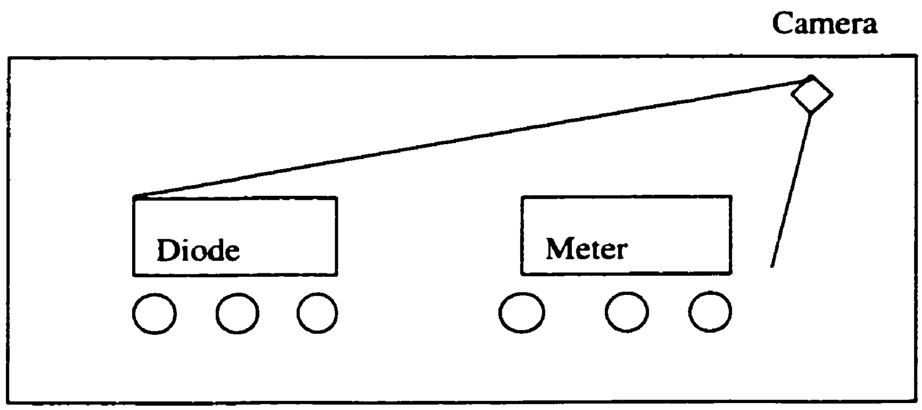


Figure 2 Diagram of the laboratory

Before week one, the students read relevant sections from the laboratory manual—what I have referred to above as the "cookbook" (see Appendix A)—and at least one additional source (see Appendix B). At the beginning of the laboratory session, the six participating students also received "pre-lab" questions (see Appendix C) which were designed to prepare them to carry out the investigation without referring, step-by-step, to the manual. Twenty minutes were allotted for work and discussion related to the pre-lab questions, and one set of answers was prepared by each group to hand in. The answers to the pre-lab questions were read by the teacher and researcher and discussed to help make sense of the students' work on the investigations.

At the laboratory

In the pre-lab questions, the students were asked relevant questions that could lay the foundation for their investigation. One of the main activities included in the pre-lab section was an opportunity for students to discuss their understanding of the tasks included in the investigations. Group members discussed the problem and how they could set up the experiment (without referring to the manual). The pre-lab activity also required students to use theory to predict experimental results. In this part, one student in each group had to make a presentation to the teacher to explain the experimental set-up. The teacher gave hints about where the students needed to change their ideas about the set up of the experiment.

In addition, the teacher gave assistance with the apparatus as required. However, the pedagogical approach of the teacher was very different than the "traditional approach," in which students are merely told the answers to their questions. In this approach, the teacher probed the students with further questions and gave only clues to assist them in their work. When it became evident that students were unfamiliar with the equipment (such as the variable resistor and how to adjust the power supply), the teacher gave them the necessary information (e.g., connect positive to positive; negative to negative in direct current).

After recording their predictions and discussing them with their partners, the students set up and performed a series of experiments in the laboratory. The students compared the results of their investigations with their initial predictions. During the entire laboratory, the teacher was available for individual consultations. Again, his role was to stimulate the students to think more deeply about the theory and concepts involved in the solution of the problem. During the laboratory activities, my role was as an observer and an interviewer. The majority of my time was spent observing and taking notes. At times I asked students questions about their activities and how they understood the pre-lab questions in order to clarify my understanding of their actions.

Evaluation of the course

In order to encourage the participants to work collaboratively in their group, 40% of students' grades were based on their group work in the laboratory and 60% of their grade was based on individual reports.

In order to consider students' attitudes toward this approach to the laboratory work a questionnaire was used with, items related with Liker scale (strongly disagree, disagree, undecided, agree to strongly agree). The items were based on studies of Hofstein, Ben-Zvi and Samuel (1976), as follows:

	SD	D	U	A	SA
1. Performing an experiment in the general Physics laboratory increases my interest in the subject.	0	0	0	0	0
2. I would like to study in this lab.	0	0	0	0	0
3. I would rather perform an experiment myself than watch a teacher perform the same experiment.	0	0	0	0	0
4. I like the equipment in this lab.	0	0	0	0	0
5. I prefer designing strategies to solve a problem by myself rather than follow cookbook.	0	0	0	0	0
6. Solving a problem in the laboratory gives me a lot of satisfaction.	0	0	0	0	0
7. It is impossible to understand the subject taught without performing experiments in the laboratory	0	0	0	0	0
8. Learning physics without doing experiments is uninteresting.	0	0	0	0	0

9. Performing experiments helps me to understand the theory material.	0	0	0	0	0
10. I prefer doing the experiment myself rather than asking the teacher what the results of the experiment are.	0	0	0	0	0
11. I am very interested in working in a general physics lab since it teaches me how to work in a neat and organized manner.	0	0	0	0	0
12. I do not like physics experiments because the observations are never exact.	0	0	0	0	0
13. Lab work in physics is boring and routine.	0	0	0	0	0
14. I prefer lessons in the classroom because the lab is terribly disorganized.	0	0	0	0	0

The following questions were included in the questionnaire

1. After studying in this laboratory, would you tell me about the advantages and disadvantages of this laboratory? Pleasc explain.

2. Do you think this laboratory will very helpful for your study in the future?

Chapter IV
Transcript and Analytical Comments

I was interested in examining how students work together to identify and make sense of the problem. The students were asked relevant questions that could lay the foundation for their investigation. Each group had to submit a laboratory report on this part, without the aid of the teacher.

Analyses of the videotapes focussed on the discussion in the group. Naturally, there comes into existence leadership in the group. The analysis below focuses on the group including Sau, Loan, Ha: Sau held the central role as he initiated most of the ideas and he was the most interactive member during the group discussion. Sau'partners, Loan and Ha, rarely volunteered an idea. Especially, Ha contributed very little to the discussion. Both appeared to wait for Sau to verbalize his thoughts. Sau knew from the pre-lab reading (see Appendix A, B & C) the main principles governing the galvanometer. Although somewhat passive, Loan and Ha were very attentive. The following episode illustrates this point.

Interaction between student-student

Question1: *How can you measure the current and voltage across a resistor?*

Sau: *It is easy. To measure the current in the resistor R, an ammeter is placed in series with the resistor, and to measure voltage of a voltmeter, it is placed in parallel with the resistor.*

Loan: *Yeah, How about question 2?*

Question2: *Can you explain the principal component of a galvanometer?*

Sau:	*It operates on the principle that a coil carrying a current in a magnetic field experiences a torque which is proportional to the current. This torque rotates the coil until it is balanced by the restoring torque provided by the mechanical suspension of the coil that it is proportional to the current in the coil.*
Loan:	*Yeah, this torque also is limited by current in a magnetic field.*
Sau:	*(Draws figure and points to the coil deflected at an angle)* *When the coil carries a current, the magnet exerts a torque on the coil proportional to the current causing the coil to twist. The deflection read on the scale is proportional to the current in the coil.*
Question3:	*Assume you have a milliammeter whose resistance is 100 Ohms and whose full-scale deflection is 1 milliampere. What must be the resistance of the Shunt needed to convert the meter to read a full-scale deflection of 100 milliamperes?*
Sau:	*(Draws the circuit)*
	I got the Shunt is 1.01 Ohm
Loan:	*Me too.*
Question4:	*Assume you have a milliammeter whose full-scale deflection is 1 milliampere and whose resistance is 100 Ohms. What must be the resistance of a series multiplier to convert this meter to a voltmeter whose full-scale deflection reads 10Volt?*
Sau:	*I used Ohms law and I got R_p = 9,900 Ohms.*
Loan:	*I agree with you.*
Loan:	*Writes the answers for the group*

In this situation, the central role adopted by Sau during the discussion phase was silently sanctioned by the two other members. The interaction in this group was clearly asymmetric. Although the attempt was made, it is not clear that Sau helped Loan and Ha to modify their understanding of the principal component of the galvanometer. There is some evidence in their discussion that the principle component of the galvanometer was eventually understood by Loan, but it is not conclusive. According to Piaget, if the information is found to be inconsistent with the student' mental framework, the student becomes confused. This confusion is termed disequilibrium or cognitive conflict. So if the individual works alone, especially when the student is still in the concrete operational stage, the disequilibrium is so great or so severe that the student can not understand the new situation.

Some people might think of the students' experience with the meter in terms of Piaget's "disequilibrium" and "accommodation." But in this situation it is very likely that the meter was so unfamiliar to the students that they did not have any established understanding about how it worked. Therefore, this situation might be thought of in terms Piaget's "assimilation," that is, this is new information for the students. However, when students work in the groups, they may help each other accommodate and assimilate new information. The important point is that when we design a problem solving laboratory (not cookbook), we need to pay attention to students' current understanding and prior experiences with the apparatus.

Sau held the central role in the group. Through interaction with his group, he had an opportunity to check and construct his knowledge. According to Tobin (1993), knowledge must be viable not only personally, but also in the social context in which actions occur. For this laboratory we recognize that every person in the group has a unique background, experience, education and priorities in life. Women are traditionally shy and quiet in Vietnam, and this group dynamic is no different.

In the traditional "cookbook" laboratory, students simply follow directions. In the problem solving approach, however, students need to discuss problems and explore the phenomena in order to think through how the problem might be solved. Therefore, I focussed on how the students understood the problem as the initial part of my analysis of their laboratory activity. The following excerpt illustrates this kind of discussion as students attempt to understand the problem:

Loan: *I think that we should convert the galvanometer into an ammeter, then into a voltmeter.*

Sau: *Yeah, I agree with you, however, first we have to measure the resistor r of the galvanometer.*

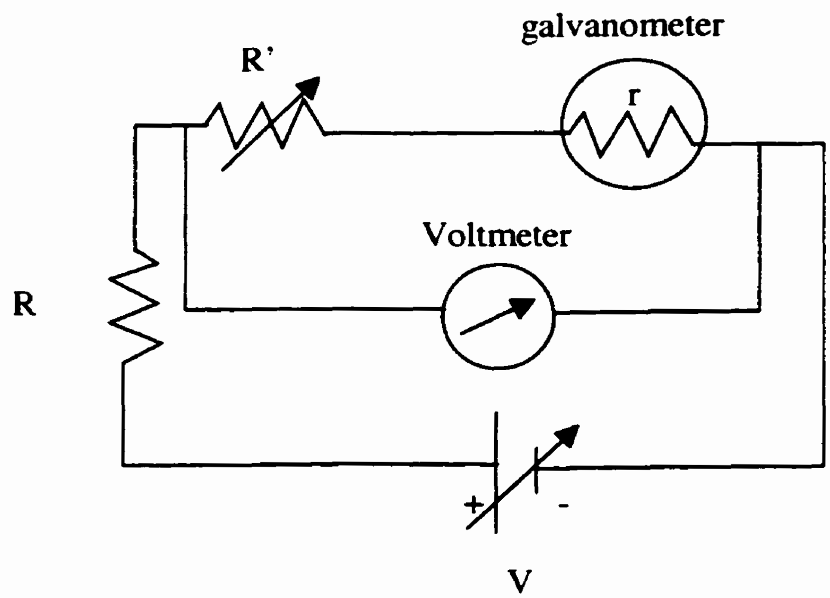
Ha: *Yeah.*

It is apparent that the students in this study demonstrated that they could understand this problem. It is quite different for students to grapple with questions and discuss a problem for themselves, as they attempt to apply what they have learned from the textbook to solve problems in the laboratory. Hopefully, this will result in more "purposive" activity in the laboratory.

In the group including Cong, Cuong and Linh, Cong held the central role. In the following excerpt Cong, Cuong and Linh attempted to design strategies to identify the resistance of galvanometer. The teacher gave hints why we have to connect the circuit in series with the galvanometer and two resistors R and R'.

Cong: *Oh, I see R' is connected to suit current power supply. We used plexiglass box 1* (see Appendix D). *How many Ohms for R and R'?*

Students used wires to connect the circuit as illustrated below:



Cuong:	*From the textbook, we have R' = 100 Ω, R = 5 KΩ.*
Cong:	*We adjust the power supply voltage so that the galvanometer reads 1mA.*
Cuong:	*We read voltmeter and from* $r_i = \frac{V}{i} - R'$ *we got r of galvanometer.*
Linh:	*Yeah, but we have to calculate the error of experiment.*
Cuong:	*Yeah.*
Cong:	*We should repeat three more times with R'=100, 200, 300Ω.*
Linh:	*Yeah, I agree with you.*

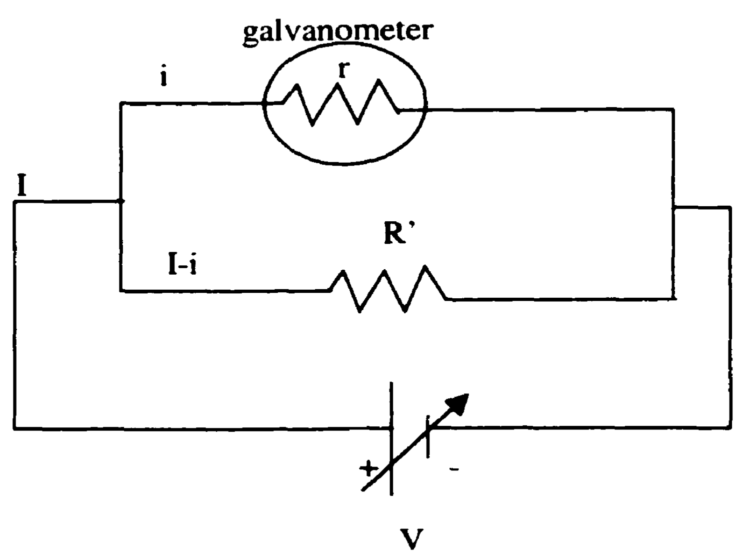
Cong was confused about the value of R and R', but Cuong helped Cong to modify the value. Linh modified this to complete the experiment. Although their ideas came from the textbook, members of this group their shared understanding' readily with each other.

The next section shows the various strategies students used for solving the problem of converting the galvanometer into an ammater or a voltmeter:

Sau: *First, we have to identify the resistance r of the galvanometer, If we want convert the galvanometer into an ammeter, we need to identify the shunt R_s and then we identify the resistor R_p to convert the galvanometer into a voltmeter,*

Loan: *I see, that in order to convert the galvanometer into an ammeter to read a full-scale deflection of 10 mA (according textbook) we need to know the resistance inside of galvanometer and then we place the resistor R_s in parallel to convert the galvanometer into an ammeter.*

Sau: *Yeah, because of according Kirchhoff's rules, the resistor in parallel R_s makes the current I decrease when it travels through the galvanometer.*



Sau: *To convert the galvanometer into a voltmeter, we place the resistor R_p in series with galvanometer, I think that R_p is very large. Because from Ohm's law V=I.R.*

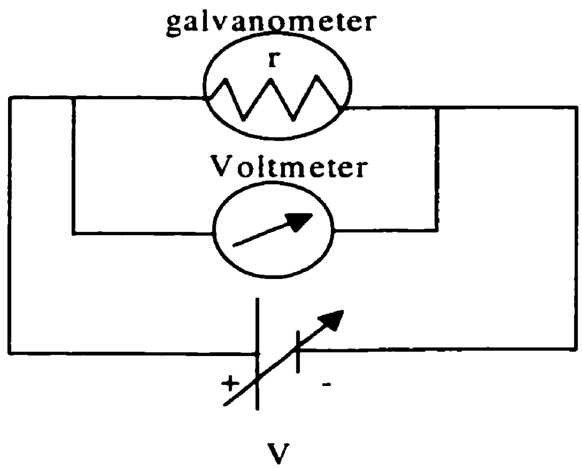
Ha: *Do you think we just use Ohm's law?*

Loan: *But, when the resistor satisfies Ohm's law?*

Sau: *Well, when the resistor R remains constant as voltage (V) and current I are varied, for example if the resistor is not varied by temperature.*

Students show that they can use the theory to solve problems. However, they can not design strategies to identify the resistance r of the galvanometer.

Sau: *Drawing the circuit such as*



Sau: *We just connect the voltmeter in parallel with the galvanometer, and then we can calculate the resistance of galvanometer.*

Loan: *(Look at textbook)*(see appendix A).

Loan: *Yeah, you are right, but look at the circuit in the textbook. We have to connect two resistors. Do you know why we have to connect two resistors?*

Sau's ideas are right, but if the students connect the galvanometer directly to the power supply voltage, the galvanometer will burn up. It is apparent that students don't know the function of the equipment so in the first experiment they can not design strategies to solve the problem.

Interaction between teacher and students

Next, after Sau shows the experimental set-up the group has decided upon, the teacher gives hints about where they need to change their ideas. I paid attention to the interaction between the group and the teacher.

Teacher: *Why do you have to identify the resistance of galvanometer?*

Sau: *We should know the resistance r of the galvanometer to place the resistor R_s or R_p when we convert the galvanometer into ammeter and voltmeter.*

Loan: *Teacher, can you explain for us about the instruments for the experiment Sir?*

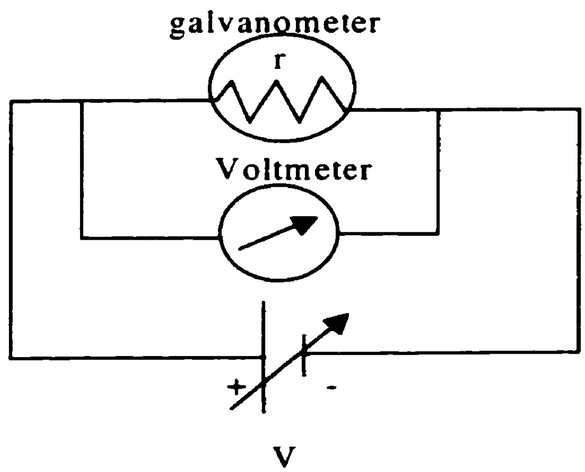
Teacher: *In this experiment, we have a power supply voltage which can vary from 0 to 12Volts, the galvanometer, some electrical wire to connect to terminals, two variables resistor box* (see Appendix D), *three plexiglass box* (see Appendix D), *and a DMM (digital multimeter), which we can use as voltmeter, ammeter.*

Loan: *How can we use this resistor box? How about the power supply voltage?*

Sau: *Teacher, in this situation we only use direct current, is that right?*

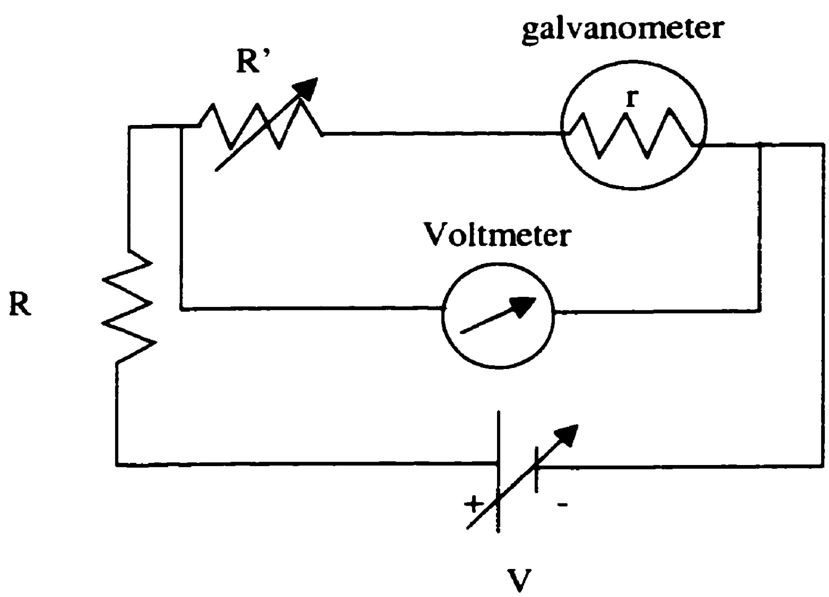
Teacher: *Yeah, be careful when you connect to the terminal of the meter.*

Sau: *(Drawing the circuit)*



Sau: *We just connect the voltmeter parallel with the galvanometer, and then we can get the resistance of the galvanometer.*

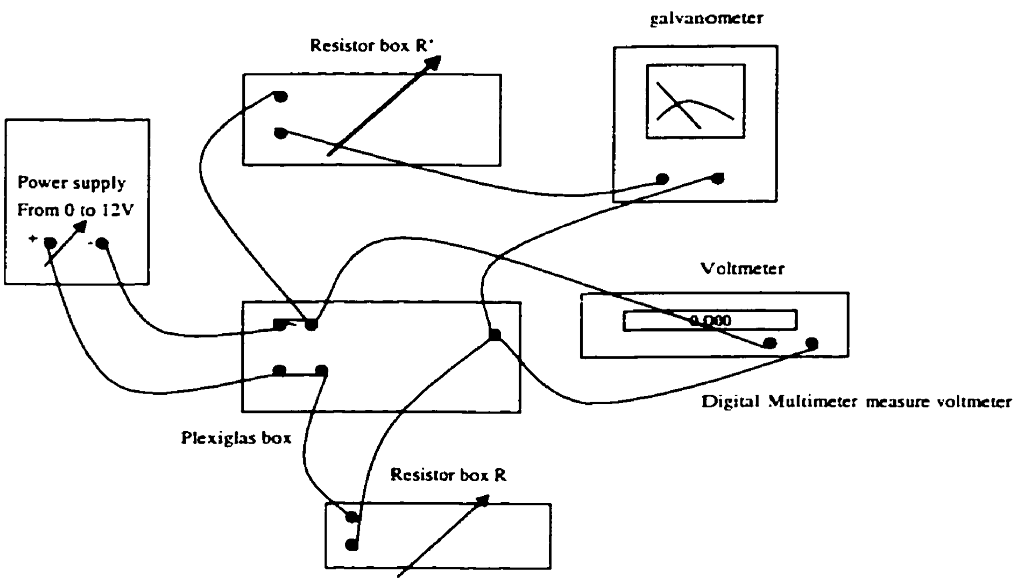
Teacher: *Yeah, you are right, but look at the circuit in the textbook, we have to connect two resistors. Do you know why we have to connect two resistors?*



Students look at the textbook and then:

Loan:	***Because the resistance of the galvanometer is too small.***
Teacher:	***Usually, we connect the resistor R' in series with the galvanometer to decrease current from power supply voltage though the galvanometer.***
Sau:	***Oh, I see, R, R' is to decrease the current to protect the galvanometer.***
Loan:	***Teacher, how can we use the resistor box Sir?***
Teacher:	***(Gives an example to adjust the resistor box)***

Next, students set up the experiment by themselves as shown in the following diagram. The schematic information they used from the laboratory manual is also shown in Figure 3.



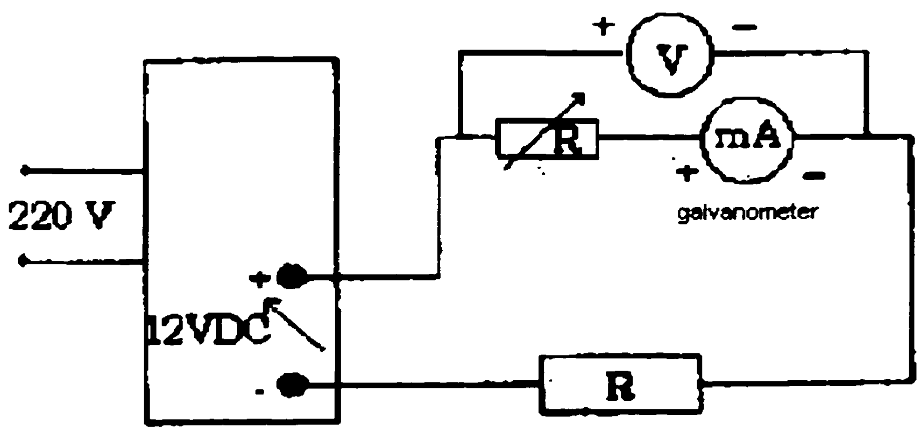


Figure 3. Identify the resistance r of galvanometer (lab manual)

Sau: *Well, we can design strategies to measure r of the galvanometer.*

Loan: *We can put the resistor box R'=100 Ohms and the resistor box R=5 KΩ.*

Sau: *From the electric circuit in the textbook we can adjust the resistor R= 5KΩ, R'=100 Ohms, adjust the power supply until I= 1mA, and from Ohm's law we have V= i. (R'+ r), We get:*

$$r = \frac{V}{i} - R'$$

Sau: *To calculate the error we measure three more again r...*

Loan: *Yeah, you are right.*

Teacher: *Why do you put R= 5KΩ?*

Sau: *To reduce the current through the galvanometer.*

Teacher: *Why are you adjusting the power supply voltage so that the galvanometer reads 1mA?*

Sau: *I think that is easy for us calculate, that is all.*

Teacher: *We should choose the value that is easy for us calculate.*

Teacher: *Why are you adjusting R'=100Ω, 200Ω, 300Ω?*

Loan: *Because we need to know the error r of experimental result.*

The teacher reminds the students how to arrange apparatus.

At this point, the teacher's question is an attempt to help the students understand the experimental set-up. While the students demonstrate some familiarity with the apparatus, the teacher's probing and assistance reveals that they have little understanding of the equipment.

For the first experiment, the students measure the resistance of the galvanometer. The teacher checks the circuit for safety and protection.

Loan makes a mistake in using the resistor box. Therefore, their result was wrong as shown in the following excerpt:

Sau: *Ha, can you adjust R = 5 KΩ?*

Ha: *OK, I did.*

Loan: *(Adjusts R'= 100 Ω).*

Sau, Loan, Ha, look at the galvanometer and the voltmeter.

Ha: *We got V = 0.22 V and I = 1mA.*

Loan: *(using calculator)*

Loan: *We got r = 120 Ω.*

Ha: *We repeat with R' = 200 Ω.*

Loan: *(Adjusts Resistor R').*

Instead of adjusting R'=200 Ω, Loan adjusted R'=222 Ω, making a mistake when she used the resistor box. Therefore, their result was wrong. Loan got r = 100 Ω, when R'=100 Ω. The second time r =120 Ω, with R'=200; the third, r =140 Ω, with R'=300 Ω.

Loan: *Why we repeat the value r but the result is very different.*

Sau: *Yeah, the resistance of the galvanometer should be only one number.*

Ha: *Something is wrong in the circuit.*

Sau: *Let me see.*

Ha: *We should ask the teacher.*

Teacher: *You should check it by yourself.*

The group checked the circuit together.

Loan: *Oh, I made a mistake because I adjusted the knob of the resistor box R' wrong.*

Sau: *Yeah, I hope so. We should measure it again.*

The group repeated the first experiment

Loan: *Yeah, that is right.*

Loan got r = 120 Ω when R'=100 Ω. The second time r =114 Ω, with R'=200; the third, r =116 Ω, with R'=300 Ω.

Sau: *We should repeat 3 more times.*

Ha: *OK.*

Loan: *I got r = 114 Ω when R'=400 Ω. r=116 Ω, with R'=500, r =114 Ω, with R'=600 Ω.*

Sau: *Yeah, the result is very good.*

$$\bar{r} = \frac{\sum_{1}^{6} r_i}{6} = 115.67 \approx 116\Omega$$

$$\Delta r_i = \frac{\sum_{1}^{6} (r_i - \bar{r})}{6} = 1.67$$

The result of experiment: $r = 116 \pm 2\Omega$ *(paper report).*

It is apparent that in this laboratory students became more independent in the research. In the traditional laboratory, students usually follow a cookbook so if their result is wrong they do not recognize the error. From a cookbook perspective, students would repeat the experiment only three times. But in this situation, students repeated the experiment six times. It is apparent that students can demonstrate the ability to make accurate measurements to the appropriate precision and judge the reasonableness of the results.

Design strategies improve

In this part of the laboratory, students had to convert the galvanometer from 1mA to 10mA DC. I paid attention to their predictions using mathematical conversions to solve the problem. Usually in the traditional laboratory, students will not know why they had to identify the resistance of the galvanometer. In this course, in the second experiment, students must identify the resistance of a shunt resistor needed to convert the galvanometer into an ammeter. They must use the resistance of the galvanometer to determine the value of a shunt resistor before they do the experiment.

From theory we can calculate:

$$R_s = \frac{ir}{I - i} = \frac{1}{9}r = 12.89\Omega .$$

(paper of Sau, Ha, Loan)

After the students in this study predicted the resistance of the Shunt resistor R_s to convert the galvanometer into an ammeter. I paid attention to another group which included Cuong, Cong, Linh: although their design strategies were drawn completely from the textbook, I focussed on the understanding, step by step, in the following excerpt:

Teacher: *How can you design an experiment to identify the shunt resistor R_s while converting the galvanometer into an ammeter?*

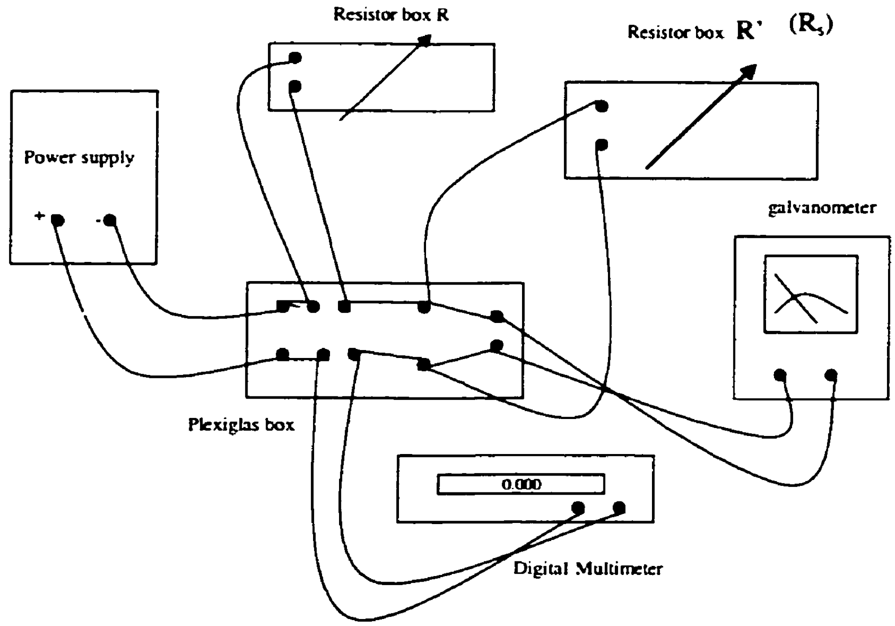
Cong: *First, we adjust the resistance of the resistor box R' to zero and the resistance of the resistor box R to 1 KΩ.*

Teacher: *Why are you adjusting the resistance of resistor R' to zero?*

Cuong: *Because first we need to adjust the power supply voltage so that the ammeter reads 10 mA. If the resistance of resistor R' is a difference of zero, the current will go through the galvanometer, we can not identify R'.*

It is apparent that the students knew each step and why they were taking it.

As the students began setting up experiment, I paid attention to whether or not they referred to their textbook. I was wondering whether the students could design strategies to solve this problem. Figure 4 shows how the apparatus was set up, and the pertinent information from the laboratory manual.



Convert galvanometer into Ammeter

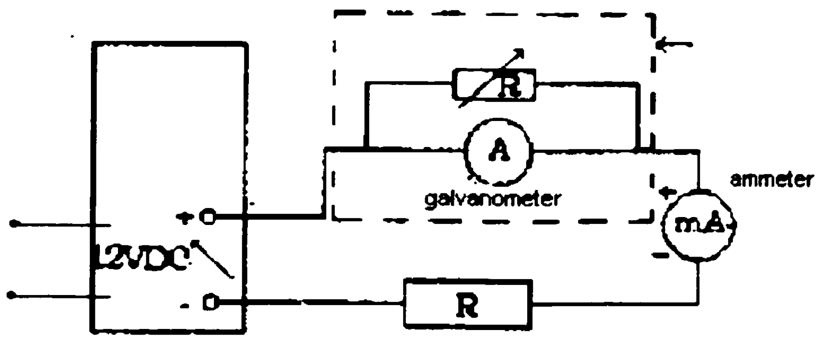


Figure 4. Convert galvanometer into ammeter (lab manual)

Teacher: *How can you identify R_s while converting the galvanometer 1mA to 10mA?*

Sau: *Adjust to R'=0, because first, we adjusted the power supply voltage so that the ammeter reads 10mA. We adjusted the* *resistance of the resistor box R'=0 to a current through the galvanometer of 0.*

Loan: *Adjusting the resistance of resistor box R at a certain value protect the ammeter.*

Sau: *Adjust the power supply until the ammeter reads 10mA and then we increase the resistance of resistor box R' by steps until the current of the galvanometer reads 1mA.*

Sau: *We stop increasing the resistance of resistor box R' when the ammeter reads 10mA and the galvanometer reads 1mA.*

It is apparent that the students can design strategies to solve the problem. In the traditional laboratory, students complete physics laboratory exercises without knowing why they took each step. Therefore, it is very difficult for students to remember this experiment. At this point, the students knew each step and why they were taking it. In this situation, students indicated that, when they understood the problem, they could think of solution processes and products.

In the third experiment, students had to convert the galvanometer from 1mA to 6 Volt DC. The students set up the experiment by themselves without assistance from the teacher.

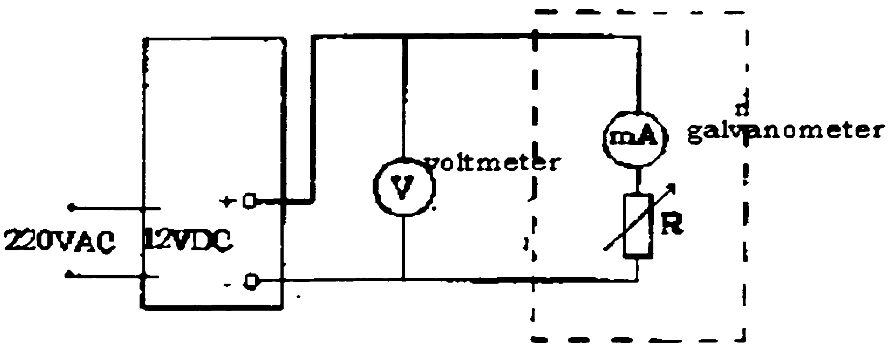


Figure 5. Convert galvanometer into voltmeter (lab manual)

The students also decided what to do with the equipment, as well as how many measurements to make. It is seen that when they become more competent with the apparatus and procedures of the laboratory, their design strategies improve.

A concern for understanding and meaning

I am interested in the paper report of the students. The following except from one of reports illustrates these students'concern for experimental results.

(In this part, they report the result of the resistor R_s to convert the galvanometer to an ammeter.)

From theory we got:

$$R_s = \frac{ir}{I-i} = \frac{1}{9}r = 12.89\Omega$$

The value of the resistor R_s from experiment 12.9Ω

The "cookbook" version of this activity does not require the students to calculate the error. In this exercise, however, students decided that they had to calculate the error.

$$\frac{\Delta R_s}{R_s} = \frac{\Delta r}{r} \Rightarrow \Delta R_s = \frac{\Delta r \times R_s}{r} = 0.22.$$

The experiment result: R_s = *12.89* $\pm 0.22\Omega$.

The result completely suit with theory

(The paper report Loan, Sau, Ha)

The students used theory to predict the result. It seemed that they understood the experimental result is never exactly accurate, so they calculated the error. In the traditional laboratory, the student's report does not include the error. With this, I think that the students in this laboratory demonstrated a deeper understanding of the experimental process.

Next, I examined the introduction and purpose sections of the students' report in terms of their understanding of the meaning of the laboratory exercise.

(The paper report of Sau)

Introduction:

To measure the current and the voltage of the circuit we use the ammeter and the voltmeter. Have you ever been interested in the components and the principles of the ammeter or voltmeter? The galvanometer reads 1mA. If you want to use the galvanometer to measure larger current or convert it to a voltmeter, what would you do?

(The paper report of Loan)

The purpose of this experiment is to understand the components and the principles of the ammeter and the voltmeter. We need a way to convert the galvanometer from reading 1mA to an ammeter that reads larger current, or to convert the galvanometer to a voltmeter.

It is apparent that Sau and Loan had a awareness of the problem.

After finishing their calculation of the resistance of the shunt resistor R_s, the textbook asked the students to plot a graph $i = f(I)$ by decreasing power supply, step by step, and reading the value on the galvanometer and ammeter. I focussed on their conclusions and the recommendations.

I	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
i	*0.1*	*0.2*	*0.305*	*0.4*	*0.505*	*0.608*	*0.705*	*0.8*	*0.9*	*1*

(Paper report of Sau)

Draw conclusions: graphing the result i =f(I) is a straight line, so we can use this graph to regulate the galvanometer reading1mA to an ammeter reading 10mA.

(Paper report of Loan)

In graphing i = f(I) is of straight lines, i=kI. Therefore, we can identify the value of I (Ammeter) if we know the value of i (galvanometer).

(Paper report of Ha)

In graphing i= f(I) is a straight lines.

In the traditional laboratory the students only draw the conclusion that this graph forms a straight line. It is seen that, when the students understand the steps of the experiment or design strategies to solve the problem, they develop a much deeper understanding for the meaning of the results. It is apparent that there were different levels of understanding for meaning among the students in this group. Ha contributed very little to the discussion of the laboratory activities; therefore, the laboratory activities contributed little to her understanding. It is seen that factors such as reading ability of the pre-lab, existing knowledge of physics are poor in Ha's case. Ha rarely attended to the discussion, leaving the teacher in a position of not knowing when to assist and change her ideas. Ha was completely "frozen" by the questions in this laboratory activity, even though she got high marks on College of Nature Science entrance examination.

Problem solving skills

According to Newell and Simon (1972) a person is confronted with a problem when he or she wants something and does not know immediately what series of actions he or she can perform to get it (p. 351). In this study I wanted to develop a problem-based laboratory activity that was realistic in terms of the everyday practices of scientists. According to Maloney (1994), if we want to stress problem-solving skills, we need to make general problem-solving procedures, such as heuristics, an explicit part of our instruction and provide opportunities to practice these procedures (p. 352). The traditional laboratory approach in Vietnam has not provided opportunities for students to practice problem solving.

Activities in the traditional laboratory on the meter have included the following:

Identify the resistance of the galvanometer, experimental set-up a ammeter have the shunt resistor, experimental set-up a voltmeter. The students follow, step by step, the procedure in the laboratory manual. Therefore, traditional laboratory work does not allow for student initiative. Students can do the experiment without knowing why they have taken each step, and there is no room for student hypotheses and error analysis. Sometimes, the student understands the experiment only after the experiment is over. Finally, the students are not taught to assume responsibility in a group.

The activities of this study are represented schematically in Figure 6

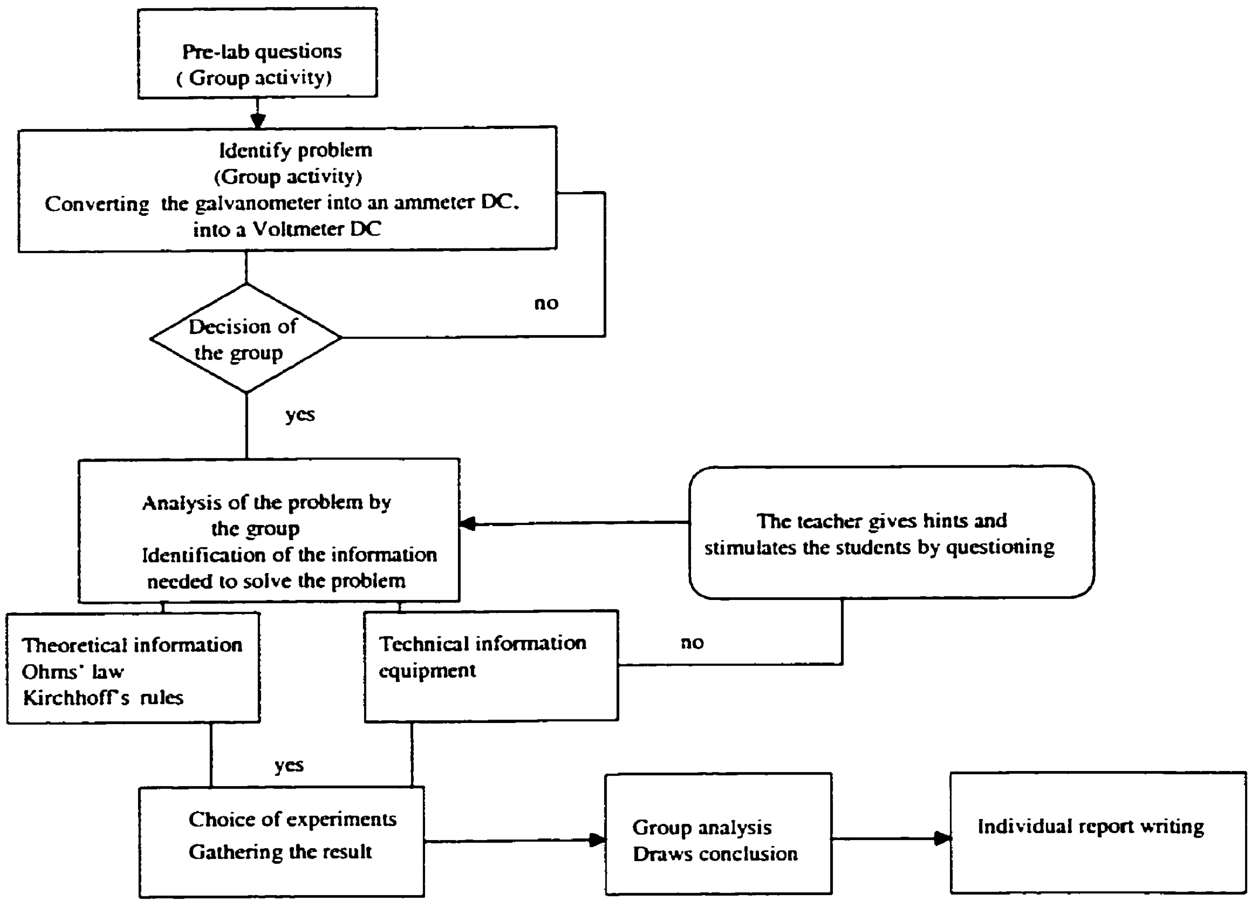


Figure 6. The laboratory activities of this study

During the laboratory activities, the students had to define problems for themselves. According to Roth (1994) when students frame their own problem, the solution processes and products are often entailed in the problem (p. 20). The students in this course also put forward hypotheses, become responsible in the group, made errors, discussed the problems and drew conclusions. The teacher only gave answers about using equipment, and stimulated the students with questions. It is apparent that, in this laboratory exercise the students had opportunities to practice the kind of problem solving skills that Polya (1945) developed in a four-step general framework for problem solving: Understanding the problem, devising a plan, carrying out plan, and looking back.

The result of the measure of students' attitude to laboratory work is presented in Table 2, below.

Table 2: The result of test of students' attitude to laboratory work.

	SD	D	U	A	SA
1. Performing an experiments in the general physics laboratory increases my interest in the subject.	0/6	0/6	0/6	4/6	2/6
2. I would like to study in this lab.	0/6	0/6	1/6	3/6	2/6
3. I would rather perform an experiment myself than watch a teacher perform the same experiment.	0/6	0/6	0/6	2/6	4/6
4. I like the equipment in this lab.	0/6	0/6	3/6	3/6	0/6
5. I prefer designing strategies to solve problem by myself rather than follow cookbook.	0/6	0/6	0/6	3/6	3/6
6. Solving a problem in the laboratory gives me a lot of satisfaction.	0/6	0/6	0/6	3/6	3/6
7. It is impossible to understand the subject taught without performing experiments in the laboratory.	0/6	0/6	0/6	5/6	1/6
8. Learning physics without doing experiments is uninteresting.	0/6	0/6	0/6	5/6	1/6
9. Performing experiments help me to understand the theory material.	0/6	0/6	1/6	2/6	3/6

10. I prefer doing the experiment myself rather than asking the teacher what the results of the experiment are.	0/6	0/6	0/6	4/6	2/6
11. I am very interested in working in a general physics lab since it teaches me how to work in a neat and organized manner.	0/6	0/6	0/6	5/6	1/6
12. I do not like general physics experiment because the observations are never exact.	1/6	5/6	0/6	0/6	0/6
13. Lab work in physics is boring and routine.	1/6	3/6	2/6	0/6	0/6
14. I prefer lessons in the classroom because the lab is terribly disorganized.	1/6	4/6	2/6	0/6	0/6

(SD: Strongly disagree, D: Disagree, U: Undecided, A: Agree, SA: Strongly Agree).

The survey shows that all of the participating students answered with agreement or strong agreement to the statements. This was consistent with my observations of students' problem-solving. It seems that the problem-solving approach helps students to increasing their interest in the subject.

If students lack the necessary prior knowledge, it is likely that many students will complete laboratory exercises without understanding what they were doing and what conclusions or meaning they should draw from the exercises. In Vietnam, high school students study physics passively and often become frustrated in the general physics laboratory when they enter university. In the recent years, high school graduates prefer going on with their studies at college or university, even though some of them fail the college entrance examination once or twice. Many of these students are now attending private colleges or the open university instead of entering a secondary professional school. As a result there is a great diversity in students' abilities and background knowledge. It seems particularly important, therefore, for teachers to identify students' ability near the beginning of the laboratory course, so that the teacher can help them. A quiz could consider factors such as reading ability, existing knowledge of physics and mathematics. If the students have adequate prior knowledge, they may construct their understanding of the inquiry's problem based on what they already know about the issue. When problems are appropriately matched to the abilities of students, attitude and motivation are increased. The following quote shows this.

A/ Khoá học này phải nói là một sự may mắn cho bản thân tôi. Những gì học được trong hai bài thực nghiệm có thể nói là những bài học quí giá nhất cho bước đầu tiên của việc thực hành thí nghiệm. Đó cũng là cơ sở cho quá trình thực nghiệm tiếp theo. Và cuối cùng, chắc chắc rằng tôi phải sử dụng những điều đã học trong khoá học này để áp dụng, vào cho công việc học tập của tôi sau này. Ví dụ như thực hành Hoá Phân tích, một ngành học, tôi rất yêu thích. Xa hơn, nó là kinh nghiệm, và giúp cho tôi phát huy được khả năng sáng tạo trong công việc của bản thân.

> I feel lucky to have participated in this laboratory. What I have learned in the first experience with a problem-solving laboratory has been very valuable. What I have learned about problem solving will be valuable in my future and I can apply problem solving skills in analytical chemistry, which I plan to major in. I understand that scientific inquiry is more creative than I thought and I am interested in this aspect.

In the traditional laboratory the students completed laboratory work without knowing why they took each step. If the student does not know where to go with the investigation, he or she is unlikely to arrive at any worthwhile conclusion. The time to think about the scientific questions, the procedural options, the analysis of data, or the development of specific scientific concepts and science process skills is usually limited. Therefore, the traditional laboratory approach may not only fail to teach students science process skills and science concepts, it may also become tediously boring. From this standpoint, I understand why students in mathematics, informatics, and biology do not enjoy the general physics laboratory. But with the problem-solving laboratory all of the students reported that they could remember every step of experimental process.

> 3. Qua quá trình thực nghiệm thì chúng ta có thể nhớ các bước và các thao tác thực nghiệm. Bởi vì làm thực nghiệm cũng giống như khi ta giải một bài toán hay làm ra được một sản phẩm thì tuyệt nhiên ta không thể nào quên các bước để hoàn thành nó.

> Because we solved this laboratory by ourselves we can remember every step of the solution. We understand why all the steps more were necessary.

On the basis of the results of this investigation, Sau and Loan enjoyed a successful experience and they became more independent in their research. From their concern for understanding and meaning, the students in this laboratory made more of an effort to understand the laboratory procedures than those who simply copied procedures from the manual. The most important result of this part of the study of this laboratory was that the students learned how to understand the problem for themselves, and had opportunities to practice problem-solving skills.

The following is what the teacher had to say about the problem-solving approach in the general physics laboratory:

1/ Ưu: Giúp cho sinh viên nắm vững mục đích, yêu cầu của bài thí nghiệm trước khi tiến hành thí nghiệm. Hệ thống các câu hỏi về việc tiến hành thí nghiệm giúp sinh viên đào sâu suy nghĩ, vận dụng vốn kiến thức về lý thuyết để giải thích những yếu tố phức tạp nảy sinh thêm trong thực nghiệm so với lý thuyết; đồng thời gợi mở và định hướng cho sinh viên phát hiện thêm những điều cần thắc mắc. Với sự hướng dẫn của người thầy và kết quả thực nghiệm phù hợp với lý thuyết, sinh viên sẽ nhận thấy được những yếu tố khoa học cần thiết trong khoa học thực nghiệm. Từ đó sinh viên sẽ cảm nhận được vai trò của thực nghiệm đối với vật lý nói riêng và khoa học nói chung. Mặt khác nó giúp cho sinh viên có cách nhìn thực tiễn hơn đối với những vấn đề cụ thể trong lý thuyết (vốn mang nhiều điều kiện được lý tưởng hóa) đã học. Từ đó sinh viên có một sự chuẩn bị tốt hơn trong việc tiếp cận với thực nghiệm cũng như trong công việc nghiên cứu khoa học sau này.

Qua khóa học này cũng cho thấy các sinh viên tiếp thu kiến thức trong hai bài thực tập rất tốt và đạt yêu cầu đặt ra.

This approach is good for helping students understand the purpose of the experiment before the investigation, the teacher's hints help students develop a profound understanding of the phenomena seen during the investigation. At the same time students must have an open mind to build their knowledge by comparing the experimental results with the theory. They see how experiments are done, and the role of experimental physics in science. This approach helps students realize that applying the theory depends on a lot of ideal conditions, which helps them prepare for science research in the future.

From this approach students received knowledge of the investigations and had a good understanding of the purpose of the exercises.

Even in those cases where student participation was not equal, for example in the case of asymmetric interaction, the group work was characterized by responsibility and independence. In this situation at least one member of the group assumed the responsibility of designing the experiment with the assistance of some suggestions from the teacher. The results show that Ha was a less able student and was not compelled to comprehend the laboratory activities, partly because the more able partner did the activities for her. It is apparent that student-student interactions may have an influence on group performance. The results also showed that there is no assurance that students automatically build these associations with appropriate prior knowledge. Here the teacher's work load is heavier. According to the teacher

> Khuyết: Người thầy sẽ phải làm việc với cường độ cao do phải trao đổi với sinh viên một lượng thông tin khá lớn. Do vậy mỗi người thầy chỉ hướng dẫn được một số ít sinh viên.

> The teacher will have intensive work, because of one-to-one work with students, it is better if the classes are smaller.

The role of the teacher in productively supporting the students' investigations in a problem-solving laboratory is crucial.

Next, the comclusions, limitations and implications of this study are put forward in chapter five.

Chapter V
Conclusions, Limitations and Implications

This chapter discusses the major results arising from the study. Following this discussion, the limitations of the study are mentioned. Finally, the implications of the research including questions for further research are presented.

Conclusions

The most important result of this study was that the students began to learn problem-solving skills that usually appear in the work of practising scientist. In a problem-solving laboratory, the students can learn to deal with scientific problem-solving without experiencing failure and considerable frustration. Such an approach to the general physics laboratory helps students become independent researchers. The main finding of the study, therefore, is that laboratory activities can be designed as problem-solving exercises in which students must use the information from theory courses to construct hypotheses, justify their hypotheses with reference to their understanding, identify problems and find their own solutions.

The study also revealed that problem solving achievement was influenced by important variables such as (a) student behavior, (b) student-student interaction, (c) the context and equipment in the laboratory, (d) students' prior knowledge, and (e) the interaction of the teacher.

This result is consistent with the model of a research-based rationale for teaching science by Clough & Clark (1994), as shown in Figure 6 below:

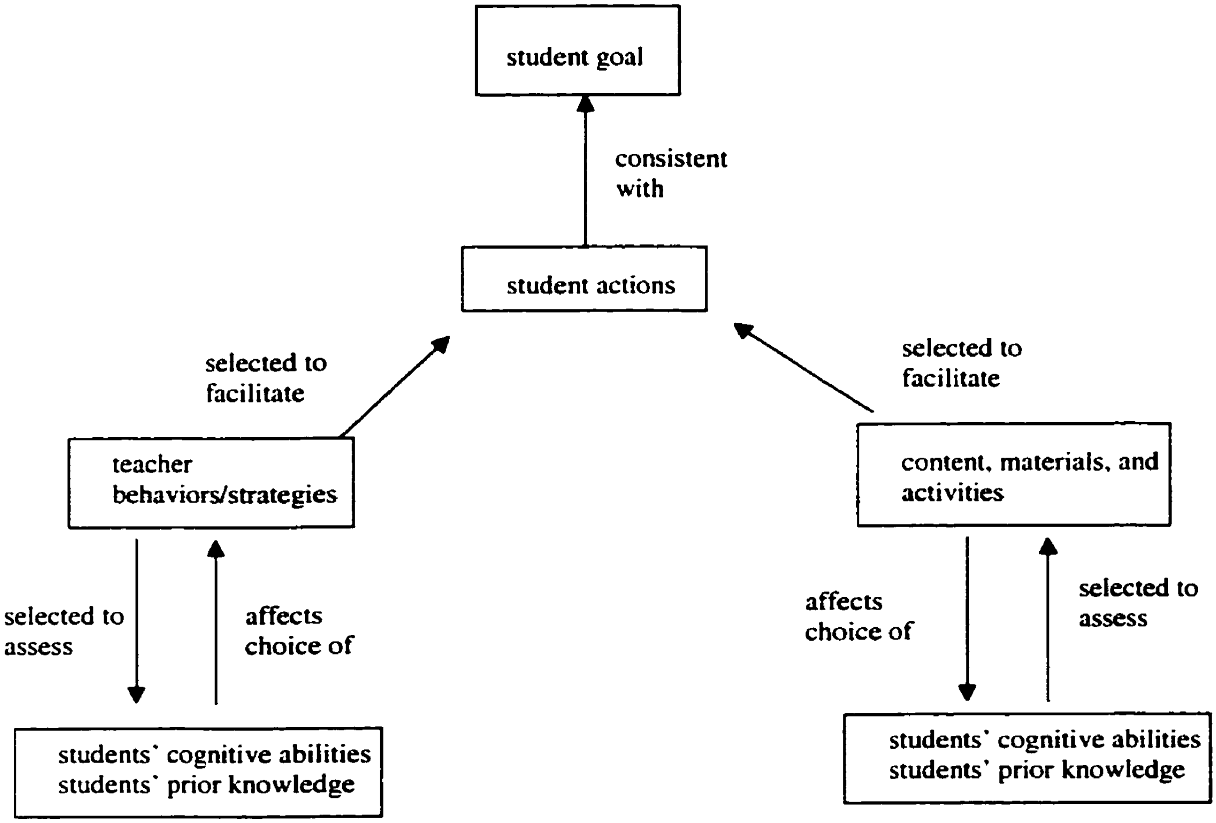


Figure 6. Components of a research-based rationale for teaching science.

It is apparent that student actions determine student goals, which means that the students have to actively study to construct their understanding rather than simply receiving solutions from the partner or teacher. If the learner is to actively construct knowledge the learner must be actively involved in the learning process (Lutz, 1996, p. 40). So this kind laboratory exercise requires students to take responsibility for their own learning.

However, the teacher has a great influence on the active study of students. Mackinnon (1993) proposed that teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts. I think some of the strategies explored in this study would be effective for this purpose; the teacher must deal with individual students and get them engaged in meaningful activities. The activities of teaching that would be useful for this kind of laboratory investigation include: (1) encouraging and accepting student autonomy, initiation, and leadership, (2) asking students to elaborate on their responses, (3) allowing sufficient wait time after asking questions, (4) encouraging students to interact with each other and with the teacher, (5) asking thoughtful, open-ended questions, and (6) asking students to articulate their theories about concepts before accepting the teacher's (or textbook) explanations of the concepts (Lochhead & Yager, 1996, p. 31). It is apparent that the constructivist learning environment is suitable for problem-solving achievement providing there is sufficient support available in the instructional program and activities of the teacher.

The context, activities, and equipment in the laboratory also influence the active study of students. Because there is a great diversity of students at the College of Natural Science the problem-solving context should be built, step-by-step, from simple to more complex aspects. Questions should ask students to focus on explanations of their laboratory observations. To begin each investigation, every student should write answers to pre-lab questions, which helps students to cue to the appropriate knowledge and shows them whether or not they know the answers. Students should also have opportunities to ask the teacher for help with questions they can not answer. The manual should require students to prepare a plan in advance for how to proceed rather than using the "cookbook" at the time.

The equipment has to suit the context of these activities in the laboratory. The College of Natural Science needs to invest in some new equipment so students can enjoy their study in the laboratory. At the beginning this study many of the students told me the equipment was too old so they did not want to study in this laboratory.

Limitations of the study

The purpose of this study was to investigate students' learning in the general physics laboratory. The results of the study were based primarily on the performance of six students in the laboratory and one activity in the laboratory. Participants were drawn from the population of first-year basic science students of the College of Natural Science, and they were not randomly selected. Therefore, some conclusions drawn from the study might not be representative of other students in the population, and other laboratory activities

Implications

Through the experiment, the head of the general physics laboratory and the teacher who participated in this study gave me some ideas about the design of the general physics laboratory activities, and how this laboratory is used in my College.

I think some research questions need to be addressed in further studies:

- How many students can study in this laboratory?
- What are the representations students construct in such a laboratory compared to those they construct in the traditional laboratory?
- Is there a significant difference in student achievement between students working in a group of three and students working in pairs or individually?

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Appendix A

Translation from laboratory manual

<u>Ammeter and Voltmeter</u>

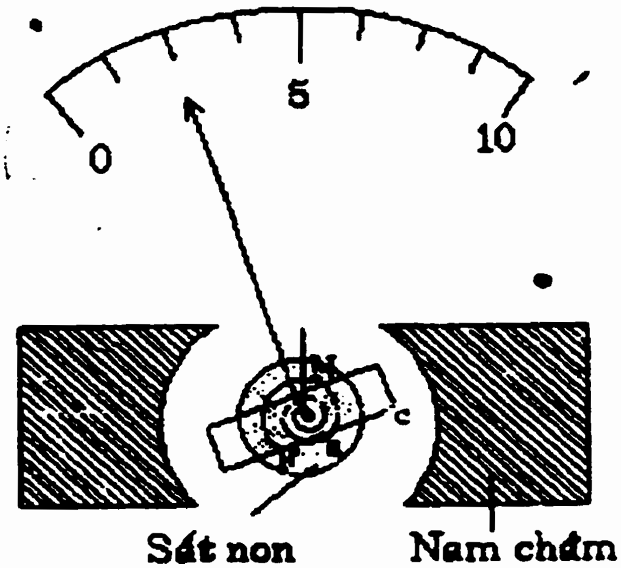
(Students read relevant sections from the main textbook)

In this experiment you will learn the way to construct an ammeter and an voltmeter from a galvanometer, as well as you the way to use an ammeter and voltmeter with Direct current (DC).

I. Theory

I.1 The galvanometer (ammeter)

The galvanometer is shown Figure 1

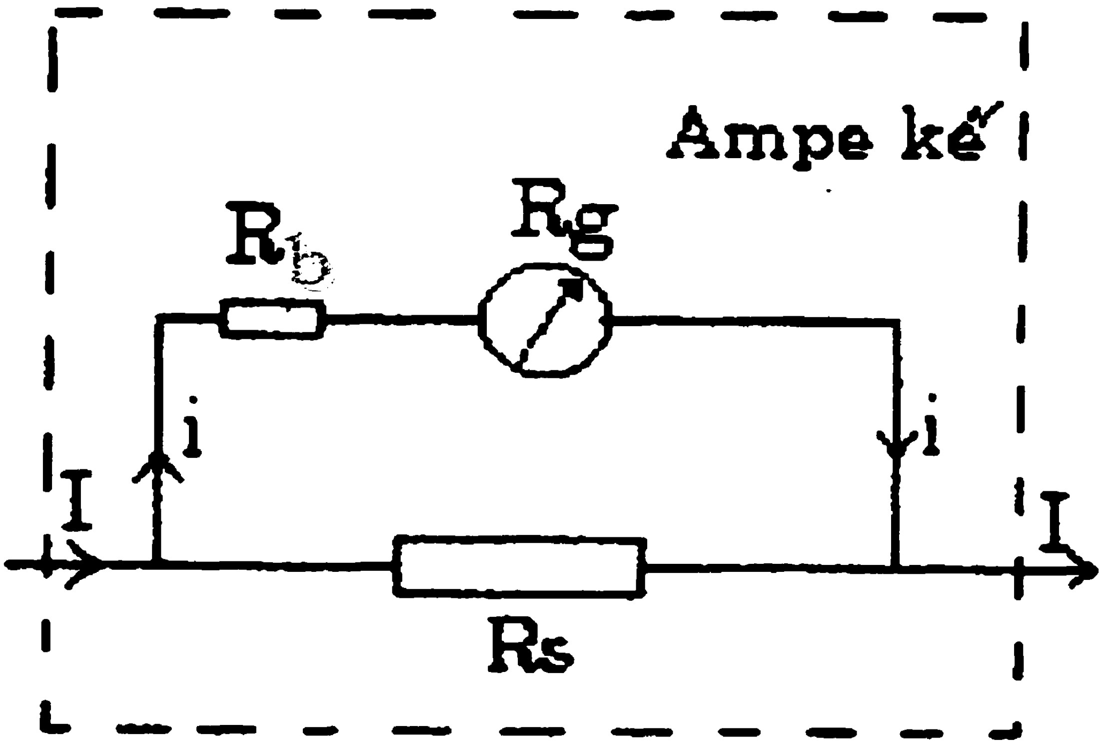


Hình 1

- The electromagnet, call the armature, consists of a coil of very fine wire wound on a solt-iron ball as a core.

- The complete armature is delicately pivoted upon a jewel bearing and is mounted between the poles of a permanent horseshoe magnet. Attached to these poles are two solt-iron pole pieces which concentrate the magnetic field.
- The pointer is attached to the armature coil. The spring opposes the rotation and brings the pointer back to the no-current position when the current ceases.

The galvanometer is used to measure a small current, measured in microamperes



Hình 2

Let R_g be value of a resistance of the galvanometer; the galvanometer is connected the resistor R_b in series to suit the current running through it.

To measure the larger currents we place a small resistance R_s in parallel with the galvanometer, called a shunt resistor.

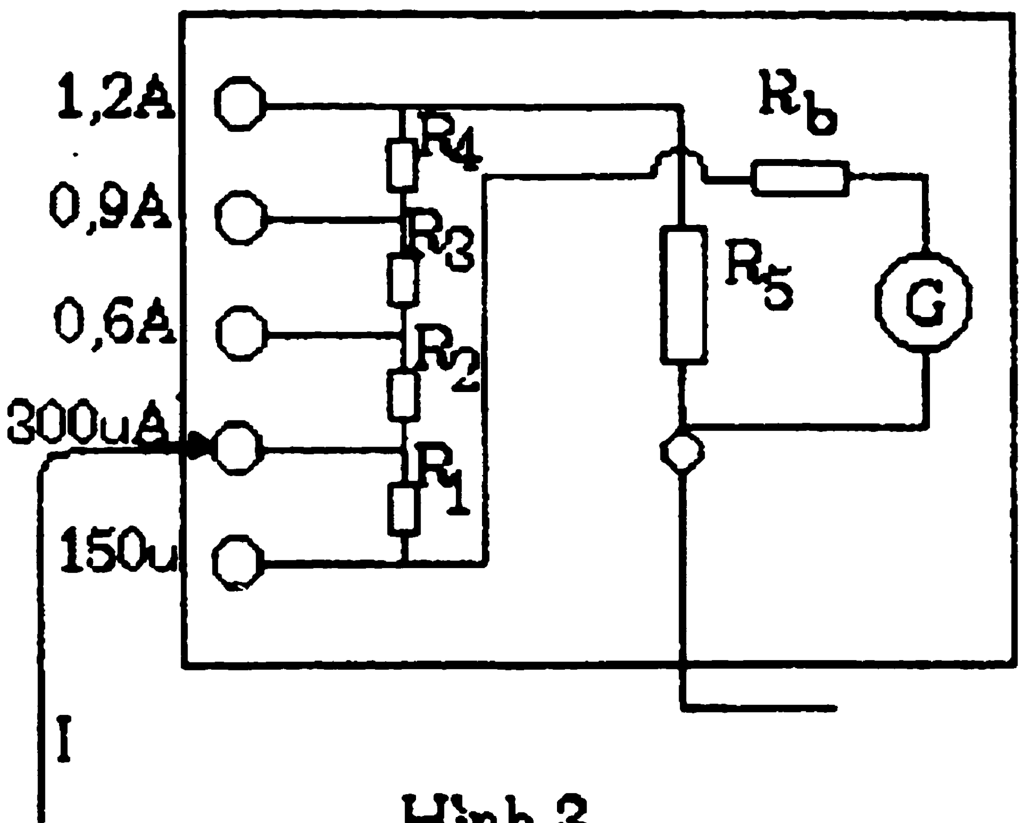
$$R_s(I-i) = (R_g + R_b)i$$

$$R_s = \frac{i}{I-i}(R_g + R_b)$$

The total resistance of R_s, R_g, and R_b is called the resistance of the ammeter.

$$R_t = \frac{(R_g + R_b)R_s}{R_g + R_b + R_s}$$

To measure different currents we use the shunt resistor, as show in Figure 3:



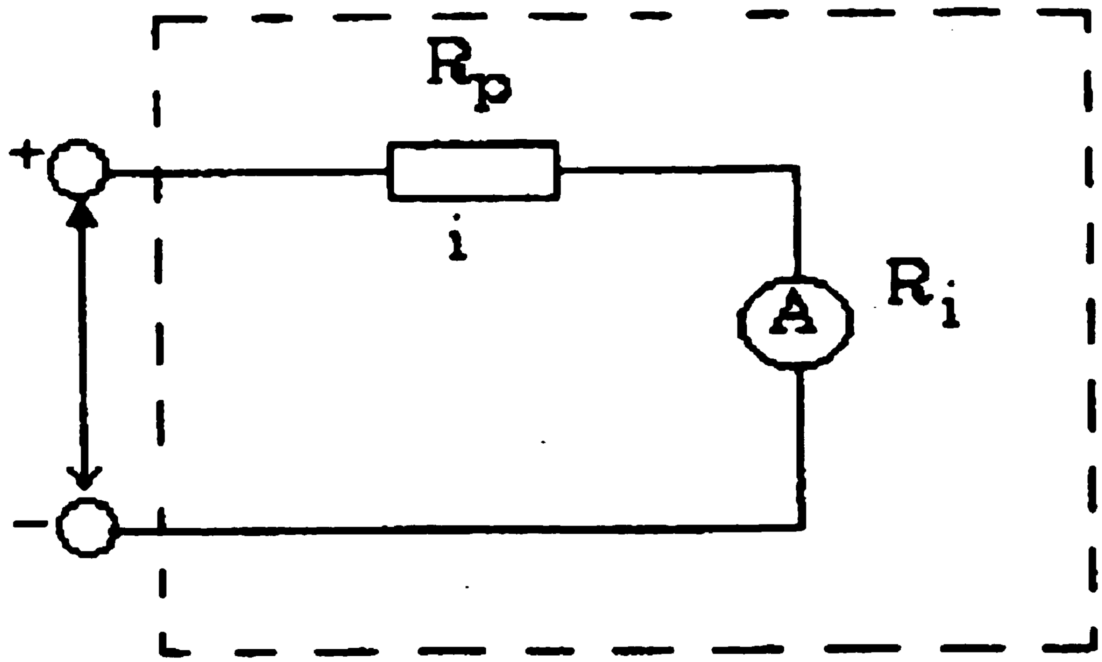
Hình 3

An ammeter can measure the current such as 150μA to 1.2A by using the shunt resistors R_1, R_2, R_3, R_4, R_5. For example, if the current is 300μA, we use the second knob with the shunt resistors $R_2 + R_3 + R_4 + R_5$.

Because the resistance of the galvanometer is too small, we should not connect it directly to power supply.

1.3 Voltmeter

The voltmeter (DC) consists of ammeter (usually the galvanometer) placed in series with the resistor R_p which has a very large resistance, as shown in Figure 6.



Hình 6

The potential difference across the resistor.

$V = (R_p + R_i).i$

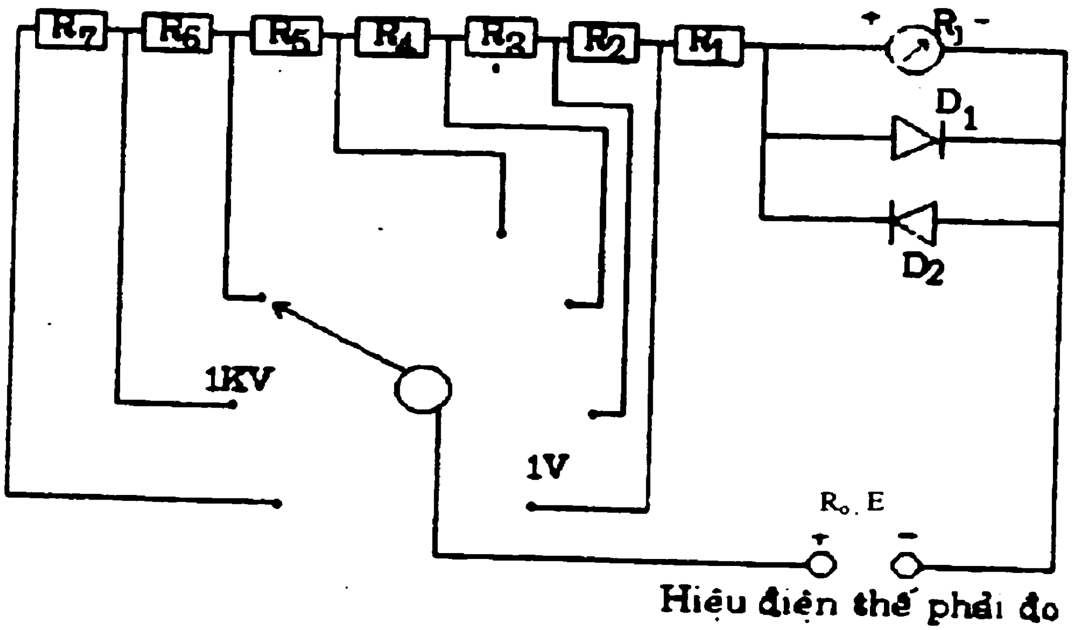
Therefore, we can read the value of voltage.

$$R_p = \frac{v}{i} - R_i \approx \frac{v}{i}$$

$$Because R_i \ll \frac{v}{i}$$

The resistance of voltmeter $R_j = R_p + R_i \approx R_p = \frac{v}{i}$

To measure the different voltages we place the resistors as show in Figure 7.



Hình 7

The larger the resistance of the voltmeter more exact is the measurement. Suppose the power supply had a voltage of E, and a resistance of R_0. The potential difference across the resistor of the voltmeter is: $v = \frac{R_j}{R_j + R_0} E$

The error is

$$\frac{E-v}{E}=1-\frac{v}{E}=1-\frac{R_j}{R_j+R_0}$$

It is apparent when $R_j \to \infty$ the error equals zero.

II. Experiment

III.1 Identify the resistance of the galvanometer:

1/ Apparatus:

a. The power supply voltage variable from 0 to 12 voltage.

b. The galvanometer 1mADC.

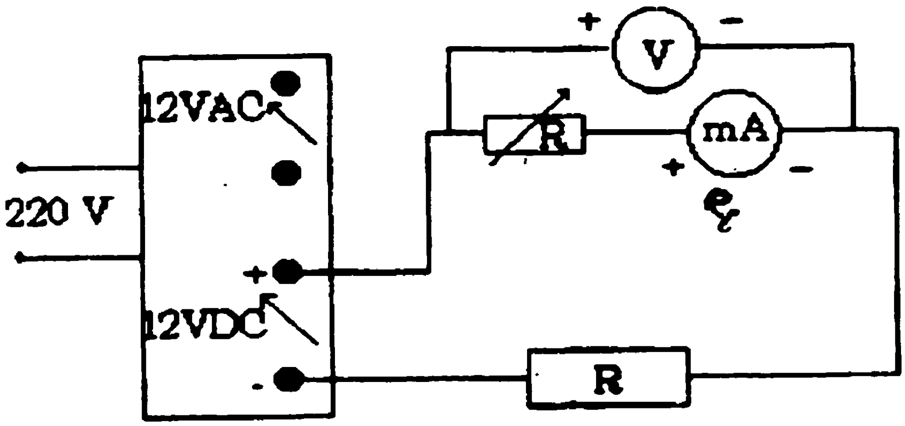
c. The voltmeter DC.

d. Two resistor boxes R and R'.

e. The Plexiglass box 1.

2/ Experiment:

- Using the plexiglass box 1, connect up the circuit as shown in Figure 9.



Hình 9

- Adjust the knob of the power supply voltage to a current of zero, adjust the resistor box R to 5KΩ.
- Adjust the resistor box R' to 100Ω.
- Turn on the power supply and adjust the power supply voltage so that the galvanometer reads 1mA and read the value on the voltmeter.
- We have $V = (R_i + R')i$
- We got $R_i = \frac{V}{i} - R'$
- Repeat the experiment with another values of the resistor box R' such as 200, 300, 400Ω.
- Calculate the error.

R'	V	R_i	$R_i \pm \Delta R_i$
100Ω.			
200Ω.			
300Ω.			
400Ω.			

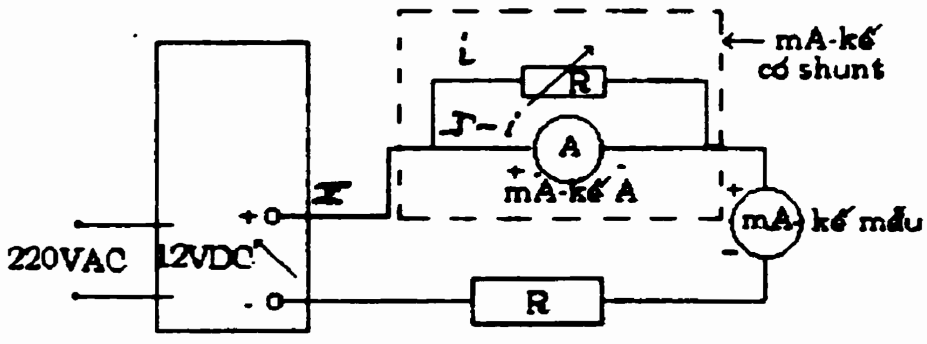
III.2. Shunt resistor for direct current.

1/ Apparatus:

- The power supply voltage variable from 0 to 12 volts.
- The galvanometer to convert ammeter 10mA
- A standard ammeter
- Two resistor boxes R and R'.

- The plexiglass box 2.

2. Experiment:



Hình 10

- Using the plexiglass box 2, connect up the circuit as shown in Figure 10 and adjust the resistor R' to zero.
- Adjust the resistor R to 1000Ω.
- Turn on the power supply.
- Adjust the knob, step by step, of power supply voltage so that the standard ammeter reads 10mA.
- Increasing, step by step, the resistance of the resistor box R' (using knob x0.1, x1, x10) so the galvanometer reads 0.9mA
- Adjust the knob of the power supply voltage so the standard ammeter reads 10mA and the galvanometer reads 1mA.
- Reading the value of the resistance R', and check with the expression:

$$R_i\, i = R_s\,(I-i)$$

- Decrease the power supply, step by step, and read the value on the galvanometer.
- Write the value of the resistance of R'

- Write the value of the current, as indicated by the ammeter and the galvanometer.

I	0 1 2 3 4 5 6 7 8 9 10
I	

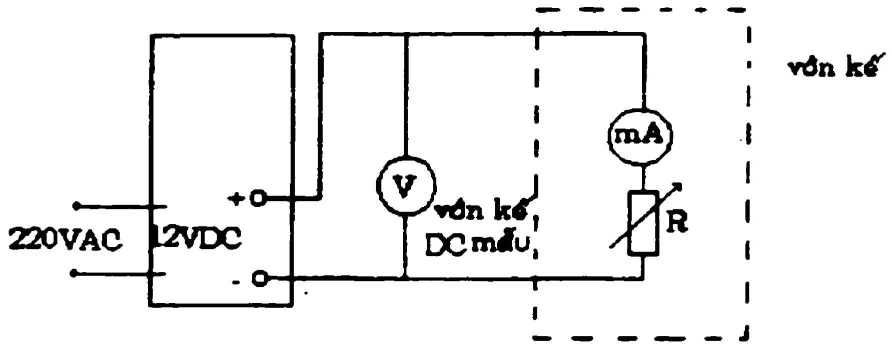
- Draw the conclusion from graph i =F(I).

III.3. Voltmeter:

1. Apparatus:

- The power supply voltage variable form 0 to 12 voltage.
- The galvanometer.
- A standard voltmeter which reads 6 Volts.
- One resistor box R.
- The plexiglass box 3.

2. Experiment:



Hình 11

- Using the plexiglass box 3 connect up the circuit as shown in Figure 11, and adjust the resistor R to 11,100Ω.
- Turn on power the supply voltage and adjusting the power supply voltage so the standard voltmeter reads 6 Volts.
- Decrease the resistance of the resistor R so that the galvanometer reads 1mA and the standard voltmeter reads 6 volts.
- Write the value of the resistance R
- Adjust the knob of the power supply voltage, step by step, and read the value of the standard voltmeter and the galvanometer.

V	0 1 2 3 4 5 6
I	

- Draw the conclusion from graph i =F(V).

Appendix A

Laboratory manual

Bài số 2

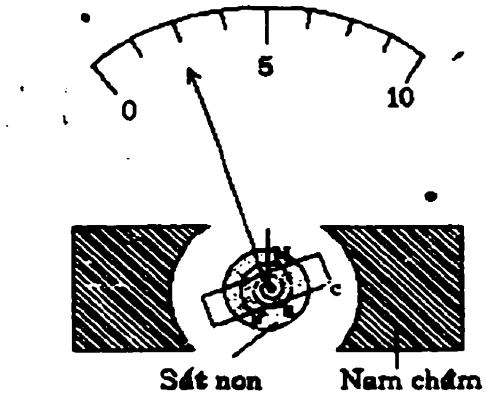
AMPE KẾ VÀ VÔN KẾ

Bài thực tập nầy nhằm giúp sinh viên nắm vững cách cấu tạo và cách sử các đồng hồ dòng và đo hiệu điện thế trong cả hai trường hợp : dòng điện một chiều và dòng điện xoay chiều.

I. LÝ THUYẾT :

I.1. Ampe kế khung quay (ampe kế một chiều) :

Ampe kế và điện kế có cấu tạo như điện kế khung quay, gồm có các bộ phận chính như sau (hình) :



Hình 1

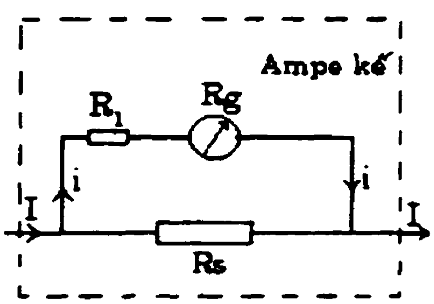
– Một khung dây hình chữ nhật c, gồm một số vòng dây, di động quanh một trục.

– Một lõi sắt non hình trụ F, đặt trong khung, cùng trục.

– Một nam châm vĩnh cửu NB; khung dây và lõi được đặt giữa hai cực Nam - Bắc của nam châm.

– Một kim bằng nhôm, cố định vào khung, dịch chuyển trước một bảng chia độ; kim cân bằng nhờ một đối trọng a. Một lò so xoắn tạo một ngẫu lực xoắn cân bằng với ngẫu lực điện từ của khung khi có dòng điện chạy qua khung.

Máy được cấu tạo như thế chỉ được dùng đo các dòng điện yếu cỡ microampe.



Hình 2

Gọi R_l là điện trở của khung, trong điện kế người ta ráp nối tiếp với khung một điện trở bổ chính R_b thích hợp với yêu cầu sử dụng (hình 2).

Để đo các dòng điện lớn hơn, người ta phải ghép song song điện kế với một điện trở R_s gọi là shunt.

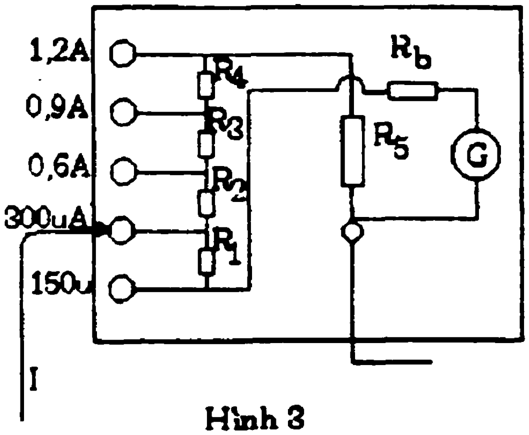
Muốn cho kim lệch hết mặt chia độ khi dòng điện I chạy qua hệ thống (ampe kế) thì ta phải chọn shunt R_s sao cho :

$$R_s(I - i) = (R_g + R_b)i$$

$$R_s = \frac{i}{I - i}(R_g + R_b)$$

Điện trở tương đương R_t của R_s, R_g và R_b gọi là điện trở của ampe kế :

$$R_t = \frac{(R_g + R_b)R_s}{R_g + R_b + R_s}$$



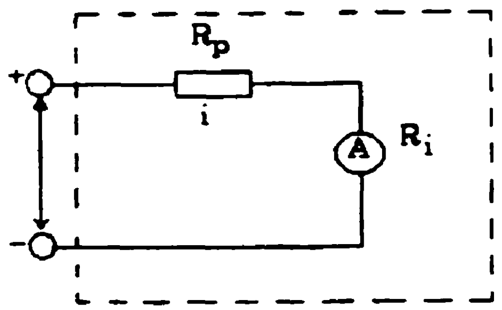
Hình 3

Để có thể đo các cường độ khác nhau người ta thường mắc các điện trở shunt với một điện kế như hình 3 : một ampe kế có thể đo được các dòng 150 μA,.. ...1,2A ta dùng điện trở shunt gồm các điện trở R_1, R_2, R_3, R_4, R_5. Thí dụ đối với dòng tối đa 300 μA, ta dùng nấc thứ hai, lúc đó điện trở shunt là $R_2 + R_3 + R_4 + R_5$ còn R_1 được coi như điện trở bổ chính.

Vì nội trở R_i của ampe kế rất nhỏ rất nhỏ nên không được nối hai đầu ampe kế vào 2 cực của nguồn điện : **cháy ampe kế.**

I.3. Volt kế một chiều:

Vôn kế chiều được tạo bởi một ampe kế (thường là microampe kế) mắc nối tiếp với điện trở phụ R_p rất lớn. Ampe kế có một nội trở R_i (xem hình 6).



Hình 6

Hiệu điện thế ở hai đầu hệ thống :

$$V = (R_p + R_i)\, i$$

Vì vậy thay gì ghi giá trị của i trên mặt của ampe kế người ta thường ghi giá trị của V và như thế ta có một volt- kế . Để cho kim lệch hết chia thì phải chọn R_p sao cho :

$$R_p = \frac{V}{i} - R_i \approx \frac{V}{i} \quad \text{vì nội trở } R_i << \frac{V}{i}$$

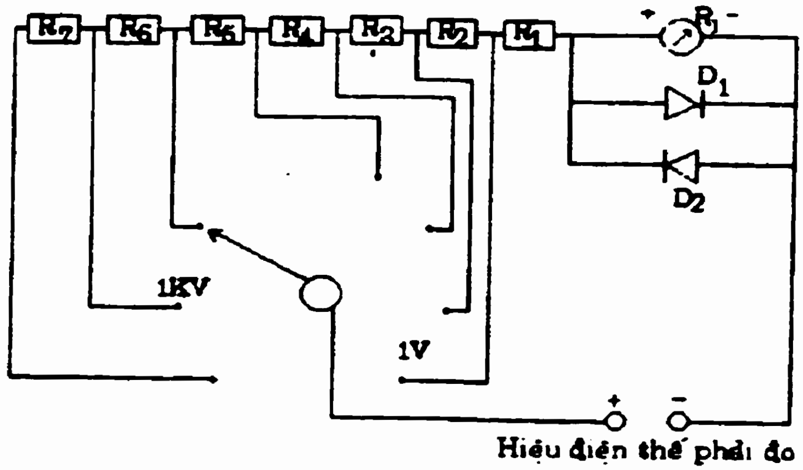
Nội trở của volt - kế: $R_j = R_p + R_i \approx R_p = \frac{V}{i}$

Muốn có nhiều giai đo khác nhau người ta mắc nhiều điện trở thí dụ hình 7. Khi đo với giai 200 V , nội trở là $R_5 + R_4 + R_3 + R_2 + R_1 + R_i$.

Nội trở R_j càng lớn thì kết quả đo càng chính xác.

Thật vậy, xét một nguồn điện thế E, điện trở R_0 (E: hiệu điện thế mạch hở của nguồn) . Khi dùng volt - kế có nội trở R_j thì số chỉ của volt- kế là :

$$V = \left(\frac{R_j}{R_j + R_0}\right)E$$



Hình 7

Sai số tương đối là:

$$\frac{E - V}{E} = 1 - \frac{V}{E} = 1 - \frac{R_j}{R_j + R_o}$$

Rõ ràng là khi $R_j \to \infty$ thì sai số tiến tới 0.

III. THỰC HÀNH :

III.1. Đo nội trở của ampe - kế :

1/ Dụng cụ:

a - Một nguồn điện 0 → 12 VDC (và 0 → 12 VAC).

b - Một mA - kế 1 mADC có điện trở nội R_i cần đo.

c - Một vôn kế 1 VDC.

d - Hai hộp điện trở R và R'.

e - Một bảng Plexiglass hướng dẫn lắp mạch điện.

2/ Thiết lập mạch và đo R_i

– Sử dụng bảng Plexiglass I để mắc mạch điện như hình 9.

– Đặt nút xoay của nguồn điện ở vị trí không , cho hộp điện trở R khoảng 5 KΩ .

– Cho R' giá trị 100Ω.

– Mở nguồn điện và hiệu chỉnh từ từ núm xoay của nguồn về bên phải để kim của mA kế A chỉ tối đa (1mA). Đọc số chỉ trên vôn kế 1 VDC.

Ta có : $V = (R_i + R')\, i$ suy ra :

$$R_i = \frac{V}{i} - R' \qquad \text{với } i = 0{,}001 \text{ A}$$

– Lập lại thí nghiệm với các giá trị khác của R', thí dụ 200Ω, 300Ω, 400Ω.

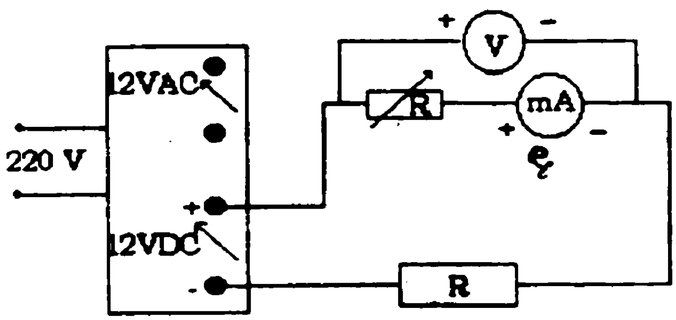
– Tính giá trị trung bình R_i và sai số ΔR_i .

– Xoay núm nguồn điện về 0.

– Tắt nguồn điện.

– Ghi các kết quả đo và tính vào bảng :

R'	V	R_i	$R_i \pm \Delta R_i$
100 Ω 200 Ω 300 Ω 400 Ω			



Hình 9

III.2. Thiết lập ampe kế DC có Shunt:

1/ Dụng cụ :

a - Một nguồn điện 0 → 12 VDC (và 0 → 12 VAC).

b - Một mA - kế A 1mADC được chuyển thành miliampe kế 10 mADC.

c - Một mA - kế 10 mADC mẫu.

d - Hai hộp điện trở.

e - Một bảng Plexiglass hướng dẫn lắp *mạch điện*.

2/ Thiết lập mạch điện và đo :

– Sử dụng bảng Plexiglass để mắc mạch điện như hình 10. Điện trở Rs là hộp điện trở R'. Cho R' bằng không.

– Cho R là khoảng 1000 Ω.

– Mở nguồn điện.

– Điều chỉnh <u>từ từ</u> núm xoay của nguồn điện để tăng dần dòng điện I qua mA - kế mẫu. Khi mA - kế mẫu chỉ I = 10 mA thì ngừng tăng (nếu núm xoay ở vị trí cực đại mà dòng I không đến 10 mA thì giảm điện trở R).

– Tăng dần điện trở R' (sử dụng các giai x 0,1 ; x 1 và x 10), dòng I qua mA kế A tăng dần từ không và dòng I qua mA- kế mẫu hơi giảm.

– Ngừng tăng R' khi i vào khoảng 0,9 mA.

– Điều chỉnh từ từ núm xoay của nguồn điện và hộp điện trở R' sao cho mA- kế mẫu chỉ I = 10 mA và mA - kế A chỉ 1 mA.

– Đọc giá trị R' và với giá trị R_i đo ở trên, ta nghiệm lại hệ thức

$$R_i i = R_s(I - i)$$

– Giảm dần nguồn điện về 0 sao cho dòng điện I của mA-kế mẫu giảm từng đơn vị một và đọc số chỉ tương ứng trên mA-kế A.

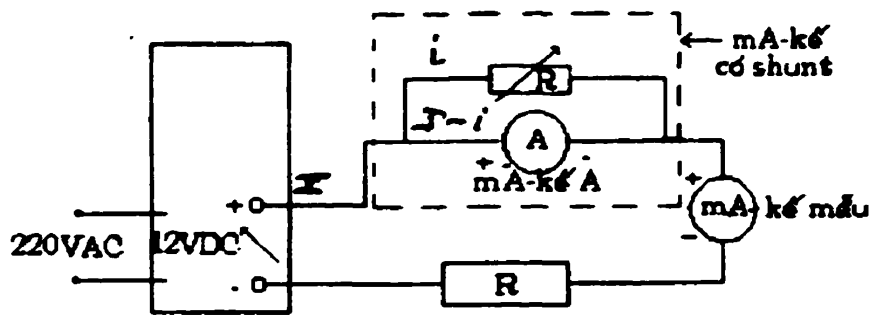
– Tắt nguồn điện.

– Ghi giá trị R_s = ...Ω

– Ghi các kết quả vào bảng :

I (mA-kế mẫu)	0	1	2	3	4	5	6	7	8	9	10
i (mA-kế A)											

– Vẽ đồ thị i = f (I) . Nhận xét.



Hình 10

III.3. Thiết lập vôn kế một chiều (vôn kế DC) :

1/ Dụng cụ :

a- Một nguồn điện 0 → 12 VDC (Bật công tắc trên nguồn điện về phía DC).

b - Một mA - kế A 1mADC được dùng để chuyển thành vôn kế 6 VDC.

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c - Một vôn kế DC mẫu, 10 VDC.

d - Một hộp điện trở R dùng làm điện trở phụ R_p

e - Một bảng Plexiglan hướng dẫn lắp mạch điện.

2/ Thiết lập mạch điện và đo :

– Sử dụng Plexiglass III để mắc mạch điện như hình 11. Điện trở phụ R_p là hộp điện trở R. Cho R giá trị khoảng 11.100Ω.

– Mở nguồn điện. Điều chỉnh từ từ núm xoay của nguồn điện để tăng hiệu điện thế ở hai đầu nguồn điện từ 0 đến 6V (đọc trên volt kế DC mẫu).

– Giảm dần R, kim của mA - kế A lệch tăng dần đến 1 mA, đồng thời kim trên vôn kế hơi giảm một chút, ngừng giảm R khi kim của hai đồng hồ chỉ gần 1 mA (trên mA- kế A) và gần 6V (trên volt kế mẫu). Tăng nguồn điện để kim của vôn kế chỉ 6V. Nếu kim của mA - kế không chỉ đúng 1 mA thì hiệu chỉnh R (nếu cần kể cả nguồn điện).

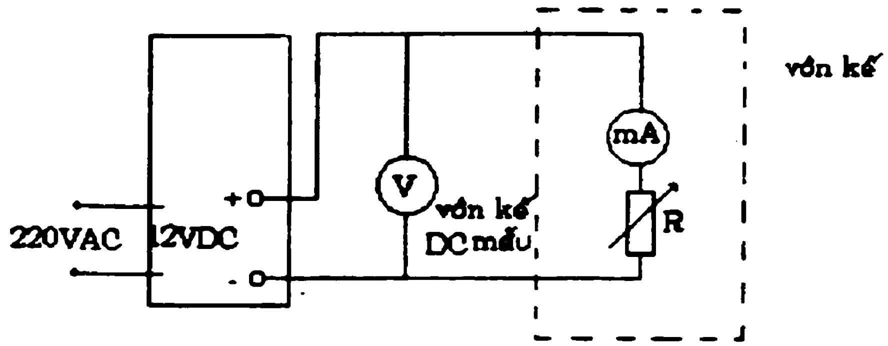
– Khi kim của volt kế chỉ 6V và kim của mA - kế A chỉ 1mA, ta ghi giá trị điện trở phụ R_p (đọc trên hộp điện trở R). Giảm dần nguồn điện <u>từng đơn vị một</u> (theo volt kế mẫu) cho đến không và đồng thời đọc giá trị tương ứng trên mA kế.

– Ghi giá trị R_p = 890 . Ω

– Ghi các kết quả vào bảng :

V (volt kế mẫu)	0	1	2	3	4	5	6 V
i (mA - kế)							1

– Vẽ đường cong i = f (V). Nhận xét



Hình 11

Appendix B

Ammeters, Voltmeters

(One additional source)

The devices which measure current, potential difference, and resistance are called ammeters, voltmeters, and ohmmeters, respectively. To measure the current through the resistor in the simple circuit, we place an ammeter in series with the resistor, as indicated in the figure 25-22.

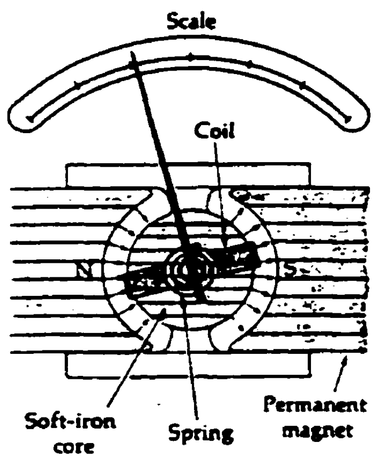


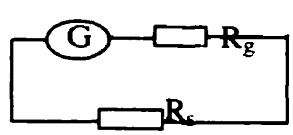
Figure 25-22
D'Arsonval galvanometer. When the coil carries a current, the magnet exerts a torque on the coil proportional to the current, causing the coil to twist. The deflection read on the scale is proportional to the current in the coil.

Since the ammeter has some resistance, the current in the circuit is changed when the ammeter is inserted. Ideally, the ammeter should have a very small resistance so that only a small change will be introduced in the current to be measured. The potential difference across the resistor is measured by placing a voltmeter across the resistor in parallel with it. An ideal voltmeter has a very large resistance, to minimize its effect on the circuit.

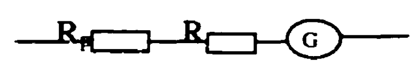
The principal component of an ammeter or voltmeter is a galvanometer, a device which detects a small current through it. The galvanometer consists of wire free to turn, an indicator of some kind, and a scale. It is designed so that the scale reading is proportional to the current in the galvanometer. The galvanometer operates on the principle that a coil carrying a current in a magnetic field experiences a torque which is proportional to the current. This torque rotates the coil until it is balanced by the restoring torque provided by the mechanical suspension of the coil.

Since the restoring torque of the suspension is proportional to the angle of rotation of the coil, the equilibrium angle of rotation will be proportional to the current in the coil. The resistance of the galvanometer and the current needed to produce full-scale deflection are the two parameters important for the construction of an ammeter or voltmeter from a galvanometer. To construct an ammeter from a galvanometer, we place a small resistance, called a shunt resistor, in parallel with the galvanometer. The shunt resistance is usually smaller than the resistance of the galvanometer. Resistors are added in series with a galvanocmeter to construct a voltmeter.

Figure illustrates the construction of an ammeter and voltmeter from a galvanometer.



Ammeter



Voltmeter

Example1: Using a galvanometer with a resistance of 20Ω, for which 5.10^{-4} gives full-scale deflection, design an ammeter which can read full scale when the current is 5A.

Since the total current through the ammeter must be 5A when the current through the galvanometer is just 5.10^{-4}A, most of the current must go through the shunt resistor. Let R_s be the shunt resistance and I_s be the current through the shunt. Since the galvanometer and shunt are in parallel, we have $I_gR_g=I_sR_s$ and $I_s + I_g = 5A$

The value of the shunt resistor should be $R_s = I_g R_g / I_s = 2.10^{-3}\Omega$.

Example 2: Using the same galvanometer as in example 1 designed a voltmeter which will read 10 V.

Let R_p be the value of a resistor in series with the galvanometer.

We have $I_g(R_p+R_g)=10V$ thus $R_p= 20K\Omega$.

Note:

The ammeter is used to measure the flow of current through a conductor somewhat as a flow meter is used to measure the flow of water through a pipe. In both cases the meter is inserted in series with the circuit under test.

The voltmeter is used to measure the difference of potential (electrical pressure or voltage drop) between two points in a circuit somewhat as the pressure gage is used to measure the water pressure in a pipe. In both cases the measuring instrument is connected in parallel with the circuit under test.

Questions:

1. Explain how a galvanometer may be converted into an ammeter; into a voltmeter.
2. Explain how you would find the resistance of a resistor using an ammeter and voltmeter.
3. Assume you have a milliammeter whose resistance is 100 Ohms and whose full-scale deflection is 1 milliampere. What must be the resistance of the Shunt needed to convert the meter to read a full-scale deflection of 100 milliamperes?
4. Assume you have a milliammeter whose full-scale deflection is 1 milliampere and whose resistance is 100 Ohms. What must be the resistance of a series multiplier to convert this meter to a voltmeter whose full-scale deflection reads 10Volt?

Appendix C

Pre-lab questions activities

I think that the pre-lab question provides advantages over a more traditional laboratory.

Pre-lab question gives the students the opportunity to interact with their group, and gives students time to think about questions and concerns before experiment.

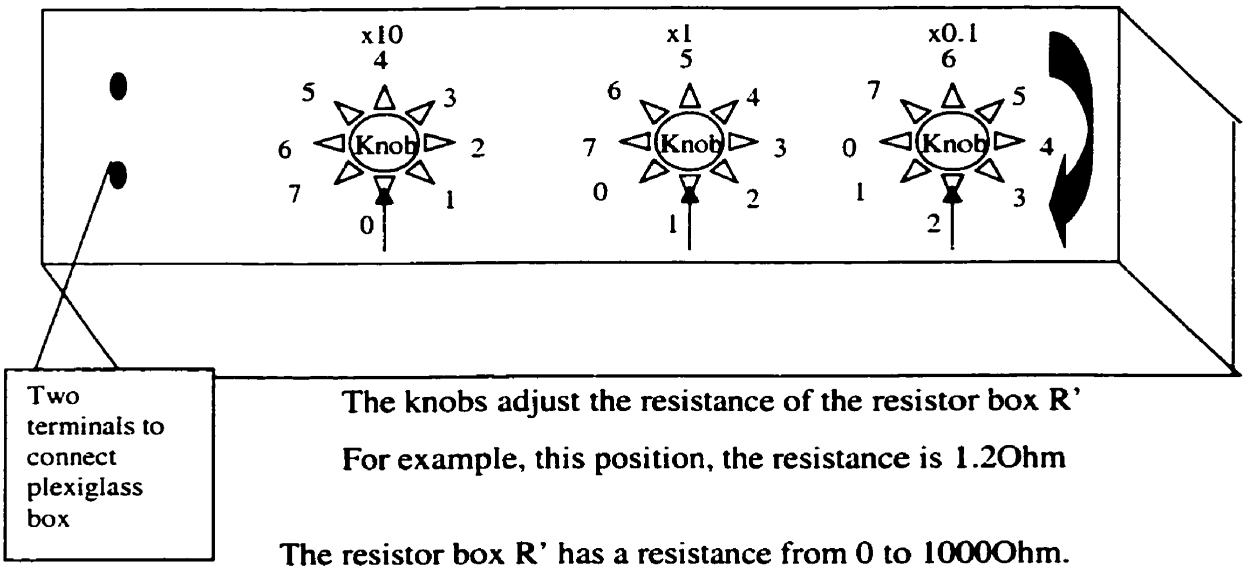
Question1: *How can you measure the current and voltage across a resistor?*

Question2: *Can you explain the principal component of a galvanometer?*

Question3: *Assume you have a milliammeter whose resistance is 100 Ohms and whose full-scale deflection is 1 milliampere. What must be the resistance of the Shunt needed to convert the meter to read a full-scale deflection of 100 milliamperes?*

Question4: *Assume you have a milliammeter whose full-scale deflection is 1 milliampere and whose resistance is 100 Ohms. What must be the resistance of a series multiplier to convert this meter to a voltmeter whose full-scale deflection reads 10Volt?*

The resistor box R'

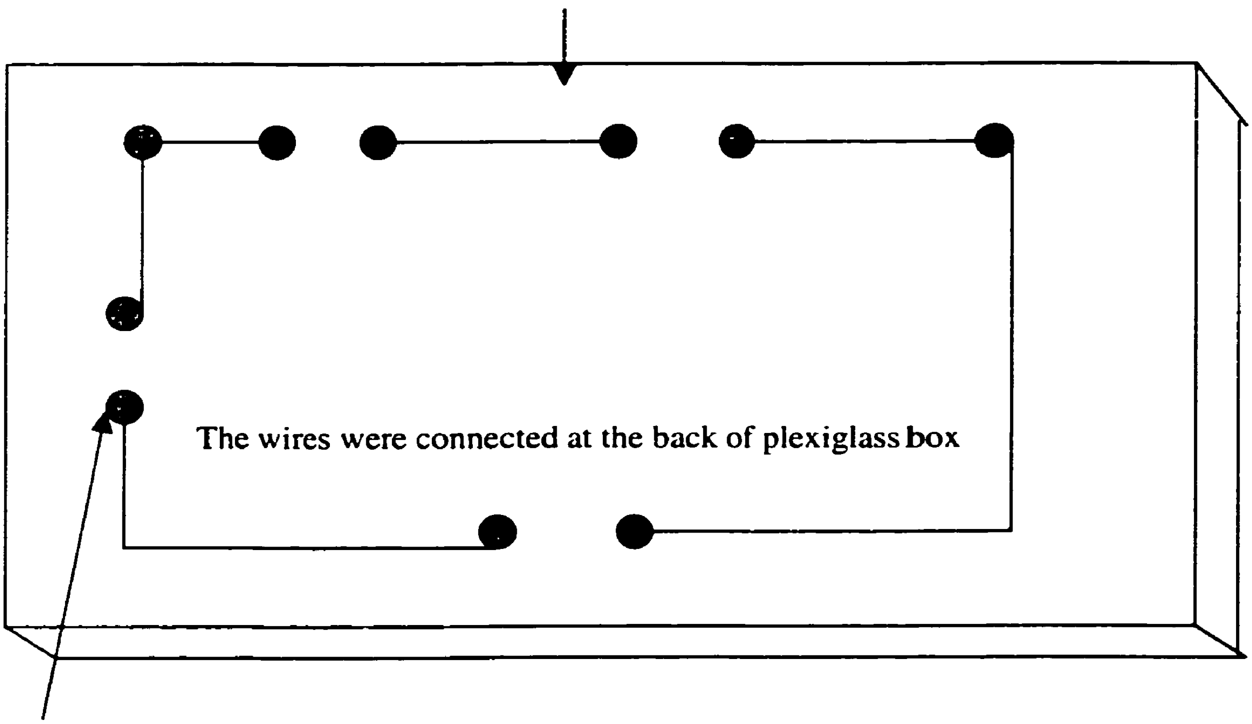


The knobs adjust the resistance of the resistor box R'

For example, this position, the resistance is 1.2Ohm

The resistor box R' has a resistance from 0 to 1000Ohm.

The plexiglass box 1



Terminals connect to the power supply voltage, the resistor box or galvanometer

Appendix E

Questionnaire

Dear friends,

I am a teacher of department of physics of College of Natural Science. At present, I am doing my thesis in Science Education at Faculty of Education of Simon Fraser University, Canada. My thesis involves the study of applying constructivist approach in general physics laboratory. I am hoping to have your help. Some of you will be invited to participate in an experiment as part of my study from September 15, 1998 to October 15, 1998. The purpose of this questionnaire is to help me to have some information about you and based on which I will invite you to participate in the study.

In order to help me, you please answer the questions given in the next part. Your answers will be used only for this study. Please note that I will make selection based on my own needs in terms of educational research.

I hope that you will answer this questionnaire fully. Thank you very much for your cooperations, and good luck in your academic studies.

Investigator

Lam Quang Vinh

Please answer the following question

- Student full Name: ______________________________

- Sex Male ☐ Female ☐

- Your marks in the following subjects on the entrance examination of College of Natural Science.

Mathematics: __________ Physics: __________ Chemistry: __________

Have you ever learned physics laboratory at high school?

Yes ☐

No ☐

Please let me know your address or phone number so that I can contact you.

- Phone number: ______________
- Address: ______________________________

Appendix F

VIETNAMESE MINISTRY OF EDUCATION AND TRAINING
NATIONAL UNIVERSITY OF HO CHI MINH CITY

College of Natural Science
Ho Chi Minh City

ACKNOWLEDGMENT LETTER

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

Dear Sir/Madam:

According to the proposed research of Mr. Lam Quang Vinh submitted to the College of Natural Science on June, 1998; The faculty of General Education of College of Natural Science permits Mr. Vinh:

1.Choosing 6 students base on his own needs in terms of educational research.

2.Teaching some topics in General Laboratory during four weeks in the Fall session 1998.

Mr. Vinh is also allowed to make his observations, to interview students and to ask students for completing questionnaires on students' attitudes forward learning laboratory and science.

The College of Natural Science is very pleased to provide his with available facilities to help him to accomplish his research.

Sincerely,

Dr. Duong Ai Phuong

Head of Faculty of General Education

The College of Natural Science.