INDIVIDUALIZED AUDIO-VISUAL
LABORATORY INSTRUCTION
IN GEOLOGY

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ABSTRACT

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The research compared individualized audio-visual geology laboratory instruction with regular instruction and also evaluated the former as a supplementary learning resource. A controlled comparison of the two instructional methods with 111 students in an introductory university geology course was followed by a longer formative evaluation using the entire class of 366. Multiple regression analysis of the controlled comparison data revealed that neither instructional method was predictive of students' test marks, attitudes towards geology, or expected grades. However, the formative evaluation revealed that in four of the eight class sections, students who had used the audio-visual instruction in addition to attending regular labs scored higher on their lab tests ($p=<.05$) than students attending regular labs only. 194 students used the audio-visual material which they felt was extremely useful for review. It was therefore decided to retain the audio-visual labs as supplementary instruction.

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INTRODUCTION

1.1 Scope of the Study

Over the last ten or fifteen years, changing educational theory and methodology have brought many radical changes to the teaching process at elementary and secondary school level. At university level, too, it is becoming increasingly obvious that the traditional lecture method of instruction is no longer adequate, on its own, to meet the needs of today's students. This is particularly true at the first year level.

First year courses are, in many ways, the most important courses that the university student takes, since they provide the foundation for his more specialized studies in following years. Yet, first year courses operate under much more severe constraints than those at a more advanced level.

To begin with, first year courses have the highest enrollment, and, with university admissions rising again, this can often mean class sizes of four or five hundred. This, however, is at a time when cutbacks in educational spending have limited the number of professors available to teach such classes. Furthermore, the kind of flexibility needed to break large classes down into small groups is seldom possible at first year level, when the students generally have a full schedule of lecture courses, and the logistics of their timetables have been worked out by computer.

Academically, too, first year courses are often caught in a double bind. On one hand, these courses must be interesting enough to catch the student's attention, and encourage him to go on in that subject area, but at the same time, the introductory course must provide a broad-based, factual introduction to the subject that will provide the foundation for more advanced studies. Some happy medium must be found between "bird" courses that are fun but irrelevant, and the kind of "heavy" courses that bury the hapless student beneath a mound of facts to be memorized (and all too soon, forgotten). In addition, current educational theory stresses the need to cater to individual student differences and learning needs. While most professors would agree wholeheartedly with this idea, they find it difficult to put into practice at the first year level. When faced with a crowd of four or five hundred, professors too often find that they must process the class in bulk, instead of adjusting to differing student learning abilities, or encouraging the development of individual learning habits.

The problem facing professors at the first year level, then, is this: how can they <u>teach</u> and ensure that the students <u>learn</u>, given the physical and academic constraints that exist?

1.2 Possible Solutions

Various solutions to this problem have been suggested, the most obvious being simply to reduce the number of students in first year classes. One method of accomplishing this is to cut back on admissions to first year. In the present economic climate, however, this is plainly out of the question, and most universities are, in fact, doing everything in their power to increase admissions to first year.

Another possible way of handling the large numbers of first year students is to break classes down into small, manageable sections. This, however, means increasing teaching staff if enrollment is to be maintained, and also creates impossible space and timetabling difficulties. Still another solution which enjoyed considerable popularity with university administrators at one time was the televised lecture. This system, however, while conserving space and teaching staff, and presenting the appearance of modernity, generally left students unenthusiastic and feeling more depersonalized than ever.

The most likely possible solution would seem to be to phase out the dependence on the large-group lecture by the use of self-instructional programmes that allow the student to cover the course material on his own, at his own speed. Individualized instruction, in one form or another, seems to offer the best chance of improving first year instruction, since it can overcome the restrictions of time, classroom space, teaching staff and high enrollment that so often hamper the effectiveness of instruction at the first year level. This is not to say that individualized instruction, per se, is a better method of instruction than the lecture. Rather, it is to point out that given the particular physical and academic constraints that exist at first year level, individualized instruction has a flexibility that the lecture format lacks. (cf. Dubin & Taveggia, 1968).

1.3 Background on Individualized Instruction

Individualized instruction is not a new idea. All of us can remember classes in primary and secondary school in which we were given (or chose for ourselves) individual project topics to work through on our own. Some of us may also have been exposed to programmed learning and self-test material. What is new is the way in which individualized instruction is now being used to replace or augment the traditional lecture format that has been the basic feature of education at all levels for so long.

Individualized instruction is, of course, not limited to the two examples mentioned above. Rather, it encompasses a countless variety of instructional techniques related by the fact that they are student-centred rather than teacher-centred. This means that, given the material which must be learned, the student takes much of the responsibility for his own learning, and the focus shifts from the teacher in the classroom as the primary source of instruction to the student as self-teacher. In order to illustrate the range of individualized learning modes, and to offer some concrete examples, it will be useful to refer to the following model, based on that given by J.V. Edling in <u>Individualized instruction: A manual for administrators</u>.

		OBJECTIVES	
		School Determined	Learner Selected
MEDIA	School Determined	A Individually Diagnosed & Prescribed	C Personalized
	Learner Selected	B Self-Directed	D Independent Study ✓

Fig. 1

The type of individualized instruction, as illustrated by this diagram, varies depending on the extent to which the learner must work within a given framework, or is given a completely free hand. Academic objectives can be set by the teacher, or chosen by the student. Likewise, the learning material itself (books, notes, audio-visuals, etc.) may be provided by the teacher, or chosen by the student. Each combination of these factors produces a different type of individualized instruction. For example, variation "D" on the diagram, where both educational objectives and learning materials are chosen by the student, represents one extreme. This kind of individualized instruction leaves the learner completely free to learn what he wants within a given subject area. At university level, this is the kind of instructional technique generally used for graduate level "Readings" courses.

At the other corner of the diagram is the kind of individualized instruction in which both the objectives and the learning materials have been determined in advance by the teacher. These can be individually determined for each student (Individually Prescribed Instruction), or for the class as a whole. The latter variety is by far the most common, and includes programmed instruction, Learning Activity Packages (Kapfer & Ovard, 1971), and modular instruction such as that presently being developed at McGill University (see Goldschmid & Goldschmid, 1972). The student may well be given a fair amount of choice within this framework (i.e. how many of the prescribed objectives he wishes to master, and which of the suggested learning materials he wishes to use), but the choices have been pre-determined by the teacher.

Between these two varieties of individualized instruction, there are programmes in which the teacher sets the objectives for the course, but allows the student to reach these any way he wishes ("B"); programmes in which the learner selects his own objectives, but is limited in the learning materials available to him ("C"); and countless variations in between.

The "A" variety of individualized instruction, in which objectives and learning materials are determined by the teacher, is the one most commonly applied to first year university courses. Here, because the courses are introductory, and must serve as the basis for later, more specialized study, it is important that the teacher have a fair amount of control over what is learned. This involves a fair amount of control over the way in which the material is learned as well, but need not mean a rigid course of instruction which the student must follow without deviation. At McGill University, for example, where over a dozen first year courses have been converted to the "modular" individualized format, students must achieve certain basic objectives, but then have a choice of several additional, supplementary objectives towards which they may work. Likewise, modes of presentation vary greatly. Most of the modules are based on print material (books, special course notes, readings, etc.) supplemented by audio-visual presentations (tape-slide, videotape, film loops, etc.) and various other practical project assignments. All of these are carefully chosen by the teacher to support the course objectives.

Under this system, the student works through most of the course material on his own, and at his own speed. Group tutorials and small lectures are generally integrated with the individual work in order to allow for discussion and questions. The responsibility for meeting the course objectives, however, is the student's.

There are several advantages to this type of instruction, advantages which counteract many of the constraints mentioned earlier. From an academic point of view, individualized instruction demands a great deal of careful preparation by the teaching staff, and is thus likely to be better organized, and more coherent than a series of lectures. Since the student must be able to work through the material largely on his own, it must be as clear and unambiguous as possible. The self-pacing aspect of the instruction allows the student to move at his own speed, and allows the teacher to concentrate on individual problems, rather than tying up the whole class for review.

From a practical point of view, individualized learning frees the university from the complicated timetabling restrictions that large lecture classes demand. Likewise, it should free the teaching staff from lectures, and allow them to operate in a much more informal way (i.e. conducting tutorials, giving special "enrichment" lectures, answering individual student questions).

There are, of course, disadvantages to the system. First of all, the time required to prepare individualized course material is often more than university staff can give. Students too, find difficulty adjusting to the responsibility of handling their own learning, and often do not make full use of the materials provided.

For universities unwilling, or unable, to convert entire courses to the individualized format, the best compromise may be to use individualized instruction as an adjunct to the existing lecture courses. In this way, the bulk of the course can still be taught by the traditional method, with individualized instructional material available for the kind of individual enrichment and review that is so difficult to handle in a large class. This, in fact, is the kind of instructional programme evaluated by the present study.

CHAPTER II

SCOPE OF THE PROBLEM

The preceding chapter has outlined some of the problems that beset first year university courses, and has shown how individualized instruction could overcome some of these difficulties. We can now turn to the examination of a specific course with operational problems similar to those already discussed where it will be shown how one variety of individualized instruction was adapted to meet the needs of staff and students.

2.1 Course Description and Constraints

The introductory geology course (Geology 010) in the Applied Science Faculty of Queen's University at Kingston is a compulsory credit for all first year students in the Applied Science programme. It is designed to give students an introduction to the principles of geology, and also to provide those who may never take another geology course with a basic knowledge of the subject. The course includes two hours of lectures per week for two terms, and a one-term laboratory section of three hours per week. The laboratory section's purpose is to teach students how to identify basic rock and mineral formations, and how to read topographic maps. The laboratory section also aims to provide students with a grounding in the scientific method (i.e. the type of deductive reasoning necessary to draw conclusions about geological structures based on the observation of individual characteristics). Enrollment in the course is high (anywhere from 350 to 450 students).

The problems common to most first year courses, outlined in Chapter I, have been particularly evident in the laboratory section of Geology 010. Traditionally, this laboratory section has been taught by dividing the class into groups of approximately twenty-five students, each group managed by a post-graduate or fourth-year student lab demonstrator. Each lab period has followed the same procedure: the lab demonstrator gives a brief half-hour lecture, then directs the students to perform the exercises set out in their lab manuals using the sample trays or maps provided. Usually, only one lab period was devoted to each topic, which meant that those who missed a lab were in trouble, although some time was generally made available for review before the examination. During the 1972-73 session, when this study began, the students in the laboratory section of Geology 010 were given one mid-term test in rock and mineral identification, then sat the final examination for the lab section at Christmas. The results of this examination counted for approximately one-third of the final mark for the entire course.

The 1972-73 session of the Geology 010 lab was unsatisfactory to both staff and students alike. The most obvious problem was overcrowding. Only one medium-sized lab room was available for each group. If all the students attended, there was very little space for experimental work, and instructors found it difficult to make themselves heard or understood. Furthermore, because of the shortage of lab instructors, and the large number of students enrolled in the course (approximately 350), some instructors had to give the same lab demonstration and lecture four times per week to four different groups.

Finally, there was almost universal dissatisfaction with the lab among the students. Many were arriving late and leaving early, and instructors reported that large numbers did not seem to have grasped even the most basic concepts. Because of the large number of facts to be memorized (e.g. the identifying characteristics of some two dozen rocks and minerals), it was most important that the students be able to review constantly. Yet, because of the shortage of staff and the rigidity of the first year timetable, it was impossible to schedule extra classes for review. Even those who wished to examine the specimen trays on their own were frustrated because the lab room was locked in the evenings and on weekends. Even when it was left open during the day, there were no instructors on hand to answer questions.

Not surprisingly, the instructors were over-worked and frustrated by the students' lack of interest. The students on the other hand, were confused, or bored, or both.

The Geology Department staff were faced with a familiar dilemma. On one hand, there was obviously a need for changes that would improve the quality of the teaching in the lab section and allow instructors to cover the course material with adequate time for review. On the other hand, there were the many restrictions of space, timetabling, staff shortages and overcrowded classes. The problem, then, was to find a solution that would reconcile these difficulties.

2.2 Possible Solutions

Many possible solutions were investigated in the hope of finding an easy solution. At first, it seemed that the most obvious remedy would be simply to reduce the number of students in each lab group. Because of the shortage of instructors and the difficulties of timetabling, this was ruled out. It became more and more apparent that there was not only a need to improve the physical operation of the lab but also to improve the presentation and content of the lab in order to link it more closely with the lecture material and to make it more interesting for the students. It was at this point that the author suggested to the Geology Department that some kind of individualized audio-visual instruction be investigated.

The author's father, Mr. R.C.E. Bray, was in charge of the overall organization of the Geology 010 lab section, and as a result of discussions with him and with the Geology Department staff, the author submitted a brief outlining ways in which individualized audio-visual instruction might be used to overcome the problems being encountered.

The brief pointed out first of all that an audio-visual mode of presentation would be well suited to the course content and might help to improve the quality of instruction. Because the lab section is concerned with the identification and recognition of rocks and minerals, and with the use of topographic maps, visual aids have always played a large part in the teaching of the course. The students are already supplied with trays of specimens, and with topographic maps, but there are many other aspects of geological formation which could be taught very effectively using coloured slides or photographs, were such materials made available. For example, slides could be used to show what rocks look like in their natural environment, or what they look like in microscopic thin section, or underground. This added dimension would take the lab beyond the mere memorization of rock and mineral samples, yet would link the specimens in the tray to the larger, more important geological concepts.

Audio-visual lab instruction, prepared in individualized packages, could also overcome the physical restrictions of time, space and number of teaching staff. Used in conjunction with the regular lab, such self-instructional audio-visual lab units would allow students to review, or pick up missed lab periods without involving the entire class, or the lab demonstrator. They would also provide an alternative mode of instruction -- one which would extend the scope of the lab and might help to keep the students' interest.

2.3 Review of Related Projects

In examining the possibility of individualized audio-visual lab instruction, the author drew largely on existing programmes of this nature, and in particular, the "audio-tutorial" system developed by S.N. Postlethwait for his Botany class at Purdue University (Postlethwait, Novak & Murray, 1969). Postlethwait developed his course in 1962, with the aim of providing instruction that would allow for the great diversity of backgrounds, interests, and capabilities of his 380 students. Scrapping the traditional format of one instructor facing a large number of students, he converted his lab room into an individual study centre. Study carrels were set up, each fitted with tape recorder and film strip/film loop projector, plus any other materials or equipment that the student might need for his lab work. The lab instruction for each week was provided via tape, and illustrated with film strip/film loop material. The taped information, however, was not merely a recorded lecture; but rather a commentary linking and explaining a wide variety of lab activities. These activities were carefully arranged in a logical sequence, based on the objectives for each week's study.

The lab operated on an open-hours system, so that students could come in whenever they wished, and spend as much time as they felt they needed. Instructors were on hand to answer questions, and met with the students in small tutorial groups each week to clear up any problems, and test the students' knowledge.

Postlethwait's experiment worked remarkably well, and has since become the prototype for many similar projects. Its greatest success was that it did improve the quality of instruction, while allowing for differing student interests and learning abilities. Students liked being able to work through the lab at their own speed, reviewing where necessary. Furthermore, the careful planning that went into designing the individualized instruction paid off. Postlethwait found that he was able to increase the content of his course, and still enable the students to meet the course objectives. From a more practical point of view, the audio-tutorial format cut down on instructors' teaching hours, yet gave them more time to give individual help to students with particular difficulties. Finally, the open-hours scheduling of the labs allowed more students to take the course with no increase in the amount of classroom space required.

Although the audio-tutorial format can be adapted to suit almost any kind of course, it appears to be most useful for practical science courses, where it allows the integration of a wide variety of activities, and the presentation of a large number of facts, while still demanding a great amount of participation from the learner. Thus, botany, biology, chemistry, and physics courses seem to have made the greatest use of audio-tutorial instruction to date.

Recently, however, the audio-tutorial method (or similar types of individualized audio-visual instruction) have been tried out on university-level geology courses as well.

Geology, in fact, seems to be a subject particularly suited to this method of instruction, for a number of reasons. (1) It has a strong visual element, in that students must learn how to identify rock and mineral specimens, recognize significant geological structures, and read topographic maps. This would suggest that slides, and other visual material, could be used to advantage. (2) It requires that the student be able to relate the samples used in the lab to geological structures in their natural form. This also would indicate that slides and other visuals could be used to link the specimens to the world outside. (3) Practical experimental work is important, and the student must learn how to apply many complicated identification procedures. This is very difficult to teach to a large class, and individualized instruction can provide the kind of personal tutoring that is often required. (4) In order to do well in geology, the student must assimilate a large number of facts, and must understand each new concept before proceeding to learn the next. Here again, individualized instruction has the advantage over large group learning, since it allows the student to proceed at his own pace, repeating and reviewing where necessary.

Research carried out on geology courses utilizing individualized audio-visual instruction has shown that these courses are successful. Yarger and Cranson (1969) developed an audio-tutorial programme for their Earth Sciences course at Lansing Community College, and found that the marks of the students in the audio-tutorial section were equal to or better than those of students receiving conventional instruction. Furthermore, they found that students were overwhelmingly in favour of the audio-tutorial as opposed to the conventional lecture-lab format (based on approximately 900 responses). Gould, Langford and Mott (1972) compared individualized audio-visual and conventional teaching approaches over a two-year period using their Earth Sciences course at St. Petersburg Junior College and found that the students receiving audio-visual instruction consistently got higher marks. Similar results were obtained by Siemankowski and Cazeau (1969) in their Physical Geology course at State University College, Buffalo, and by Ladd and Brown (1973) at Boston College. At the University of Michigan, McClurg (1971) compared 98 audio-tutorial laboratory students with 14 students in a regular geology programme, and although he found no significant difference in test marks between the two groups, he did find that students had a much more positive attitude towards the audio-tutorial format. Finally, an extensive evaluation of an audio-tutorial geology laboratory has been carried out by Sweet, Bates and Maccini (1971) at Ohio State University, with a class of 280 students.

Unlike the previously-mentioned studies, this was not a comparison of different methods of instruction, but an evaluation of the effectiveness of audio-tutorial geology teaching at university level. It was found that the audio-tutorial instruction was academically sound, since students were able to meet course objectives. Sweet, Bates and Maccini also found that the audio-tutorial mode of presentation enabled them to increase the content and complexity of the course material while still ensuring that students reached the course objectives. Furthermore, 80% of the students expressed a positive attitude towards the audio-tutorial method of instruction.

Mention should also be made of the geology courses developed by the Open University in Great Britain (see Wilson, 1971). Open University courses are designed for individual home study, since the university has no central campus. The core of each course is formed by specially written teaching texts, incorporating self-assessment tests. The other components of the teaching system are television and radio broadcasts, tutor-marked assignments and computer-marked assignments. The introductory geology course also includes a home practical kit, sent to each student, containing a specially designed petrological microscope, rock specimens, thin sections of some of the rocks, mineral specimens, crystal and fossil models.

The Open University courses provide a particularly interesting example of individualized instruction, since students must not only work through the course material on their own, but isolated from other students in the course as well. Evaluation to date has shown the Open University courses to be largely successful, and the careful teamwork that went into the preparation of the courses has produced very impressive teaching materials.

In summary, then, it appears that an individualized audio-visual method of instruction for university-level geology is academically sound and popular with students. It should be noted in connection with student attitudes that previous studies have only tried to measure student attitudes towards the type of instruction, either regular or individualized audio-visual. There do not seem to have been any efforts made to examine the effects of the different modes of instruction on students' attitudes towards the course in general. It might be expected that students would be more interested in a particular course if they liked the way in which the course was presented. There have, however, been no studies in the field of geology to test this assumption.

It does appear, however, that there is evidence to support the following statements in favour of individualized audio-visual instruction:

(a) test marks of students receiving individualized audio-visual instruction are equal to or higher than marks of students receiving regular instruction (Gould, Langford

& Mott, 1972; Ladd & Brown, 1973; Siemankowski & Cazeau, 1969; Yarger & Cranson, 1969.)

(b) students prefer individualized audio-visual instruction to regular instruction. (McClurg, 1971; Postlethwait, 1962; Yarger & Cranson, 1969).

(c) the individualized audio-visual format allows more efficient use of classroom space and teaching staff, allowing more time for instruction and review without having to reduce class size. (McClurg, 1971; Postlethwait, 1962; Sweet, Bates & Maccini, 1971).

On the basis of this evidence, it was decided that the author and Mr. R.C.E. Bray would prepare individualized audio-visual lab instruction for part of the Geology 010 lab course, to be used as an adjunct to the regular lab instruction. The effectiveness of this new mode of instruction was then to be tested during the 1973-74 academic year to see whether it might overcome the practical administrative problems mentioned earlier and improve the quality of the Geology 010 lab.

CHAPTER III

DESCRIPTION OF THE PILOT STUDY

During the 1973-74 session, the pilot project for an individualized audio-visual system of geology lab instruction was carried out by the author and the Geology Department staff at Queen's University in Kingston. The purpose of this pilot project, as already stated, was to set up an alternative form of lab instruction for Geology 010, and to evaluate its practical and academic feasibility. The results of this pilot project were to be used by the Geology Department to determine: (1) whether the entire lab section should be converted to an individualized audio-visual format; (2) whether the audio-visual lab instruction should be used as an adjunct to the regular lab instruction; or (3) whether the audio-visual lab instruction should be discarded in favour of improving the regular lab instruction.

3.1 Procedure

It was decided that audio-visual lab units would be prepared for the first four units of the lab section only (Minerals, Igneous Rocks, Sedimentary Rocks, and Metamorphic Rocks) since these units contain a great deal of factual and theoretical information, and have caused most difficulties for students in the past. These audio-visual lab units were to be made available in one of the lab rooms during the evening and on weekends for supplementary study and review for any students in Geology 010 wishing to make use of them. A senior student was to be on hand while the audio-visual lab room was open to issue equipment and to answer questions. In order to evaluate the project, it was decided that records would be kept of the names of students using the audio-visual lab material, to see whether any conclusions could be drawn from their mid-term and Christmas examination marks. Students' opinions of the project were to be measured by a questionnaire handed out after the lab course had finished. Opinions were also to be gathered from the audio-visual lab demonstrators and other Geology 010 teaching staff.

3.2 Preparation of Materials

The audio-visual lab material was prepared by the author and Mr. R.C.E. Bray in consultation with the professors handling the lecture section of Geology 010. The first step in the development procedure was to decide on the overall objectives for the four audio-visual lab units. It was decided that students who worked through all four units should be able to: (1) apply to any unknown specimens the systematic procedure for identifying rock and mineral specimens; and (2) relate the individual specimens to the rock formations as they occur in the field, and to the appearance of rocks as seen under the microscope.

It was also intended that the audio-visual lab units would help develop the kind of methodical reasoning that goes beyond mere memorization of the samples in the specimen tray to handle scientific deduction about larger rock formations. Finally, it was hoped that the audio-visual format would spark the students' interest, and encourage them to learn more about geology.

The success of the two main objectives was to be evaluated by considering students' marks on the mid-term rock and mineral identification test and on the Christmas examination. Although both these tests were set by the Geology Department, and were not specifically keyed to the objectives of the audio-visual lab units, it was felt that the objectives for the audio-visual lab units were essentially identical to those of the regular lab units.

The two sub-objectives were to be evaluated by responses to a questionnaire handed out at the end of the lab course to all students who had used the audio-visual lab.

Obviously, both testing instruments were far from exact, but it was felt that they would be adequate for the purely formative evaluation required for the pilot project.

Once the overall objectives for the audio-visual lab units were determined, individual objectives were set for each unit, and a logical sequence of instruction and lab activity worked out that would accomplish these aims. As the instructional sequence was drawn up, the most effective way of illustrating each concept was decided (i.e. slides, specimens, lab notes, textbook, etc.) so that the audio-visual lab units would contain a wide and varied selection of activities, all fitting the final objectives.

The spoken (taped) portions of the labs were kept as short as possible. Where background information was deemed necessary, a brief spoken introduction was supplied and the student was then referred to the relevant pages of his textbook or lab notes. Furthermore, slides were used sparingly, and only to illustrate concepts that could not be illustrated adequately by the samples in the specimen trays. In this way the author hoped to avoid the pitfall of making a flashy "slide-show" that would not give the student an opportunity to try and find the important features in the actual minerals and rocks themselves. Instead, slides were used to broaden the scope of the basic lab material. For example, slides were provided to show alternate samples of the specimens in the trays, especially in cases where the specimen could exist in many different colours and shapes (e.g. quartz). Slides showing microscopic thin sections of rock were also included to explain the concepts of texture and composition (e.g. grain size, clastic and crystalline formation, etc.) that are often not easily visible to the naked eye in the hand samples. And finally, as many slides as possible were included that showed how the rocks and minerals being studied might appear in the field or underground. As additional visual material, two excellent sets of commercial photographs of rocks and minerals were purchased, which were to be posted on the bulletin board in the lab room.

The format for each of the four audio-visual units followed roughly the same pattern:

1. Brief spoken introduction, definition of key concepts (as listed in the course lab notes), and statement of the unit objectives.
2. For Units 2, 3 and 4, a brief reminder of what was covered in the previous unit(s).
3. Step-by-step explanation of the identifying characteristics of the specimens, using the specimens themselves plus slides of alternative specimens, or thin sections, as illustration.
4. Step-by-step identification of one of the specimens on the tray, on the basis of the identifying characteristics set forth earlier, and using pre-printed identification charts.
5. Identification by the students of the remaining samples on the tray, the answers to be checked against a list provided.
6. Illustration of field occurrences of rocks and minerals using slides, and referring to the specimens in the sample tray wherever possible.
7. Closing summary, and suggestions for further activities (e.g. looking at the photographs on the bulletin board).

The content of the audio-visual units was exactly the same as that of the regular labs, in that both covered the principles and procedures for rock and mineral identification. Furthermore, the student was required to perform the same lab experiments in the audio-visual units as those set forth in the regular lab (i.e., correct identification of all samples in the tray). However, the audio-visual units extended the range normally covered in the regular lab by the addition of the slides. Rather than being limited to a mere identification exercise, the audio-visual lab units linked the routine identification of specimens with the larger concepts of geological deduction.

The slides used for the audio-visual lab units were borrowed from personal collections in the Geology Department, and from one of the Ward's commercial series devoted to microscopic thin sections. These slides were then duplicated at the University by the author. The Queen's University Radio Station, CFRC recorded the tapes, each one beginning and ending with a different piece of "rock" music.

The finished tapes were each approximately 20 minutes long, although it was expected that the student would require a minimum of one and one-half hours to complete all the lab activities included with each unit. Roughly ten to fifteen slides were used with each unit.

3.3 Implementation

The four audio-visual lab units underwent developmental testing by the Geology staff and graduate students before the final revised versions were prepared for the students.

These were available for student use at the beginning of October, 1973. Five Kodak Carousel slide projectors, Sony tape recorders and earphones were purchased with the aid of a $1,000 grant from the Arts and Science Faculty at Queen's. Carrels were to have been built for the audio-visual lab, but the Geology Department moved into a new building shortly before classes began in September, and the class was lucky to have electricity by the beginning of October. Therefore, the audio-visual lab was forced to use a very makeshift arrangement, with slide projectors set up on one of the long lab tables at the back of the lab room, and screens taped to the rear wall. The audio-visual lab was publicized in the lecture periods during the preceding week, and by information sheets passed out to all students. It was to be open from 5:30 p.m. to 10:30 p.m. Monday to Friday, and from 8:30 a.m. to 1:30 p.m. on Saturday. The lab assistants were to be final year or graduate students in geology, some of whom were already helping teach the regular lab section.

3.4 Data Gathering

In order to keep track of the numbers of students using the audio-visual lab, a record log book was provided for the lab assistants in which to sign the students in and out. Students were asked to leave their student cards with the lab assistant when signing out the audio-visual material. In this way, it was hoped to keep track of the names of the students, and ensure against theft of the equipment or materials.

A questionnaire to assess the students' opinions of the audio-visual lab units was handed out to all students who had used the audio-visual lab by the time the lab course finished at Christmas. Comments were also collected from lab demonstrators and geology staff in an informal way.

Two sets of marks were examined: (1) those on the mid-term test covering only rock and mineral identification; and (2) those on the Christmas examination which included rock and mineral identification.

3.5 Results

Four sources of information were used to evaluate the success of the audio-visual laboratory: (1) student use of the lab, (2) students' marks on mid-term and Christmas tests, (3) students' responses to the questionnaire, and (4) comments from professors, instructors, and lab assistants involved with the audio-visual lab. The results in each of these categories are summarized below.

3.5.1 Student Use of the Audio-Visual Lab Units

Almost as soon as it opened, the audio-visual lab was completely swamped by students wishing to use it. Most of the students' sudden enthusiasm was due to the impending mid-term rock and mineral identification test. Nevertheless, in its first two weeks of operation, the audio-visual lab was used voluntarily by over 100 students (out of a total class of 339), many of whom came back several times to work through all four units. In order to accommodate as many students as possible, it was necessary to limit students to one and one-half hours each, and to ask them to sign up to use the lab in advance. However, this arrangement seemed to be satisfactory and the students appeared to have enough time to complete the activities set forth on the tape. In addition, some of the professors volunteered to man the lab during the day for students who wished to use it between classes, and this helped take much of the pressure off the evenings.

Predictably, once the mid-term test was over, attendance at the audio-visual lab dropped off almost entirely. However before the Christmas examination the lab was busy again, and by the time the term was over, 154 students (roughly half the class) had been there at least once.

3.5.2. Examination Results -- Mid-Term and Christmas

The students' examination results showed that, of the 154 students who used the audio-visual lab material, 107 scored higher on the Christmas rock and mineral identification test than they had on the mid-term, and 20 of these raised their mark from a failure to a pass grade. Although the final average marks on the Christmas test were the same (72%) for both those who had and those who had not made use of the audio-visual lab units, the audio-visual users raised their marks by approximately 10% per student between October and Christmas, compared to a 5% increase per student among those who only attended the regular lab. This would seem to discount the usual assumption that it is only the more intelligent students (who would do better anyway) who make use of supplementary learning resources.

3.5.3 Questionnaire Results

The questionnaire (which had been designed by the researcher) was handed out during the first week of second term to all students who had used the audio-visual lab material. Ninety questionnaires were returned, of which 62 were completely filled out. The questionnaire was in two parts, the first of which presented a series of statements with which the student was asked to agree or disagree on a five-point Likert scale. Each question was phrased in both positive and negative form, so that a comparison of the responses on both parts of the question could be made. The second part of the questionnaire contained several multiple-response questions, and an open-ended section for the students to write down their own comments.

A summary of the questionnaire responses is found in Appendix A. The results indicated an overall positive attitude towards the audio-visual lab units. Specifically, the students indicated that they:

- thought the audio-visual lab units were interesting, clear-cut, informative, and extremely useful for review.
- liked having the answers available when they did the identification tests.
- found that the slides clarified many concepts, but thought there should have been more slides.

- approved of the choice of "rock" music (that is, most of them did. There were a few rude comments).
- found that the hour and a half slot gave them enough time to finish each lab unit, and, strangely enough, weren't bothered by the makeshift viewing arrangements.
- had an overall positive opinion of the audio-visual lab but were opposed to the idea of replacing the regular lab with the audio-visual format.

The general feeling among students seemed to be that the audio-visual units were an excellent source of review and back-up information to the regular lab and lectures.

It was interesting to note that of the 62 students whose questionnaires were tabulated, 42 had completed all four audio-visual units. The most common reasons for using the audio-visual lab units were (1) to review for the exam, and (2) to clarify points covered in the regular lab period.

Some of the specific comments made by students are listed in Appendix B.

3.5.4. Comments From Geology Staff and Lab Instructors

Informal discussion with the lab assistants, instructors, and Geology 010 professors indicated that they were all enthusiastic about the audio-visual lab units. They felt, however, that the prime value of the audio-visual lab lay in its use for review and for clarification, and felt that it should continue as an adjunct to the regular lab, rather than a replacement.

Staff and instructors were impressed by the number of students who had used the lab, and one of them remarked, "It's embarrassing how successful it is!"

3.6 Discussion and Conclusions for Further Research

Although it was impossible to draw any firm conclusions from a purely formative evaluation, there were nevertheless a few general conclusions that could be made about the audio-visual lab as it operated during the 1973-74 session.

First of all, the lab material appeared to be academically sound. This could be partly assumed from the difference in examination results between the mid-term and the Christmas examination for those who did and did not use the audio-visual lab material. Of course, many other factors could have contributed to this difference, but nevertheless, it did appear to indicate that the audio-visual lab units helped students do better on the Christmas examination.

It also appeared that the audio-visual lab units had fulfilled their overall objectives (see page 24). The students' ability to carry out the rock and mineral identification procedure did appear to have been improved by the audio-visual lab material, as the test and examination marks showed. Moreover, 65% of the students answering the opinion questionnaire thought that the audio-visual lab units had indeed helped them pass the Christmas examination. It was a little more difficult to determine whether the audio-visual lab units helped students relate individual specimens to larger geological formations, since this concept was dealt with in the lecture section of the course as well. However, 55% of the students who answered the questionnaire thought that they had been helped in this respect by the audio-visual lab units, and nearly 75% stated that the slides (most of which were chosen to fulfill this objective) clarified many concepts for them.

Again, it was difficult to determine whether the audio-visual lab units had improved students' methodical reasoning abilities, and 50% of them answered "neutral" to this item on the questionnaire. Likewise, just under 35% agreed that the audio-visual lab units had increased their interest in geology, which is hardly overwhelming proof of the success of this particular objective. However, 65% of the students said that they liked this way of presenting geology, and over 70% thought that the audio-visual lab units were worthwhile. Finally, a full 80% of the students said that the audio-visual lab units were useful for review. Thus it appears that the audio-visual lab pilot project fulfilled its academic objectives and proved its instructional worth.

Turning to the various practical problems which the audio-visual lab was meant to overcome, it was difficult to draw any conclusions about the practicality of converting the entire lab section to the audio-visual format. On paper, at least, a fully-equipped audio-visual lab with ten to twelve carrels, open twelve to fourteen hours per day, could accommodate all the students without overcrowding, and without having to resort to scheduled hours. However, with only five sets of equipment, no carrels, and limitations on time and lab assistants, it was impossible to do more than speculate about the audio-visual lab's ability to solve the problems of overcrowding and lack of instructors. Most of the time, in fact, the audio-visual lab room was severely overcrowded and the lab assistant had his hands full setting up equipment, signing students in and out and answering questions as well.

However, even under these less than perfect conditions, the audio-visual lab worked remarkably well as a source of independent review, taking much of the pressure off the regular lab periods, and giving the lab instructors a chance to deal with particular problems rather than general overall review. The student questionnaire also stated very clearly that the students saw the audio-visual lab's main value as a source of review, and not as a replacement for regular lab instruction. It was therefore felt that the original intention of trying to convert the entire Geology 010 lab course to the audio-visual lab format might be defeating the purpose of the whole exercise, namely, to improve the course as a whole by providing for different student learning abilities and preferences. One of the Geology professors remarked, in fact, "There are so many students in this course, with so much pressure on them in first year, that they need all the learning tools they can find!" It was therefore felt that the best solution to the problems that have beset Geology 010 in the past might well be to continue with both styles of lab presentation.

The students in Geology 010 do not have to be pushed into doing review work. It is absolutely necessary for most of them if they are to pass the course, and the great number of students who used the audio-visual lab material during the pilot project proved this. The need among the students appears to be not so much for improved instruction (although this is important) but for a chance to review or repeat sections they missed or did not under[illegible]

It was with this major objective [illegible]d that plans were made to revise and improve the a[illegible]isual lab units for the 1974-75 session, and to evaluate the lab's academic and practical value under more carefully controlled conditions.

CHAPTER IV

PROBLEM STATEMENT

The problems which the current research set forth to investigate fall into two main categories. There are first of all those problems which were examined under controlled experimental conditions and the resulting data analyzed statistically. Secondly, there are those problems which were investigated from the point of view of the Queen's University Geology Department in order to determine the Department's future decisions about the audio-visual lab. Most of these latter, decision-oriented problems were investigated in a non-statistical, formative way.

4.1 Experimental Questions

The researcher carried out a comparative study of the audio-visual and regular modes of lab instruction for a two-week experimental period in order to determine whether either method alone or a combination of the two was preferable in terms of: (1) students' test marks, and (2) students' attitudes towards geology as a whole.

During the remainder of the first term, when the audio-visual lab material was available to all students on a voluntary basis, the researcher monitored the use made of the audio-visual lab material by the original test sample in order to determine whether those students who used the audio-visual lab units in addition to attending the regular lab classes had an advantage in terms of; (1) students' average

Christmas mark in the lab section; (2) students' attitudes (at Christmas) towards geology as a whole; and (3) students' expected grades (at Christmas).

4.2 Geology Department Questions

The Geology Department hoped to determine from this study whether the audio-visual lab worked, both academically and practically. Specifically, they wanted answers to the following questions, based on the operation of the audio-visual lab during the first term of the 1974-75 session:

a. Did students use the audio-visual lab units?

b. What did the students and lab demonstrators think of the audio-visual lab?

c. Did the audio-visual lab material improve students' attitudes towards geology as a whole?

d. Did the audio-visual lab material appear to help students on their tests?

e. Did the audio-visual lab appear to provide an adequate opportunity for review?

f. How much did the audio-visual lab cost to set up and to run?

g. Is it feasible to extend the audio-visual lab?

CHAPTER V

PROCEDURE

5.1 Research Plan

5.1.1 Experimental Aims

The experimental portion of the research was carried out in two stages: (1) a short period of controlled experimental comparison using a sample group of students drawn from the Geology 010 class, and (2) a longer period of less controlled evaluation in order to provide additional back-up data, using the same sample of students. The first part of this research will henceforth be referred to as Stage I, and the second part as Stage II.

5.1.1.1 Stage I Hypotheses

Two hypotheses were tested in Stage I, and these are stated in null form as follows:

a. There will be no difference in the scores on a cognitive test between students receiving audio-visual lab instruction, students receiving regular lab instruction, and students receiving regular lab instruction with the option of additional audio-visual lab instruction. Students' university entrance marks and previous studies in geology will have no effect on the results.

b. There will be no difference in attitude towards geology between students receiving audio-visual lab instruction, regular lab instruction, or regular lab instruction with the option of additional audio-visual lab instruction.

Students' university entrance marks and previous studies in geology will have no effect on the results.

The following operational definitions were employed:

Audio-visual laboratory instruction: laboratory instruction in which the material is presented via tape-slide format using lab notes, photographs, diagrams and specimen trays as well. The instruction has been prepared in a series of self-contained packages to be used individually by students.

Regular laboratory instruction: lecture-demonstration format by which the instructor meets with a group of approximately 25 students, gives a short lecture and demonstration, then directs students to perform the identification exercises set forth in the lab notes, using the specimen trays provided.

Cognitive test: a test on the contents of the first laboratory session, given to all students at the beginning of the second lab session. This test consists of the identification of ten mineral samples. Similar tests occur at the beginning of every lab except the first one. They are set by Queen's staff and count towards the student's final mark in the laboratory section.

Attitude towards geology: indicated by responses to an attitude questionnaire, based on the five-point Likert scale ~~model,~~ administered as both pre and post test. The questionnaire was designed and validated by the researcher during the pilot project period (see p.51).

University entrance marks: obtained from students' entrance records, and used as a measure of students' academic standing at the time of entering Queen's University. These marks are presented in percentage form.

Previous studies in geology: as indicated by students' response to an item on the attitude questionnaire asking whether or not they had ever taken a geology or earth sciences course before.

A separate research design was used to test each of the two hypotheses. The first hypothesis was tested using a Post-Test-Only Control Group Design (Tuckman, 1972,p.109), where the dependent variable was cognitive test scores, the independent variable was type of lab instruction, and the moderator variables were university entrance marks and students' previous geology studies (see Fig. 2). No cognitive pretest was given, mainly for reasons of time. However, since the experimental period began with the first laboratory session, it was assumed that all students would have roughly the same knowledge of the subject. In any case, students' university entrance marks (expressed in percentage form) and previous studies in geology (if any) were used as moderator variables, in order to isolate the effects of differing prior academic achievement. Students were randomly assigned to control and experimental groups.

$R\ X\ Y^1 Y^2 0$

R = random assignment of subjects
X = independent (treatment) variable
  a) individualized audio-visual laboratory instruction only
  b) regular laboratory instruction plus optional audio-visual instruction
  c) regular laboratory instruction only (control)
Y^1 = Moderator variable #1 (university entrance marks)
Y^2 = Moderator variable #2 (previous studies in geology)
0 = dependent variable observations (cognitive test scores)

Fig. 2

Research Design - Stage I - Hypothesis 1

The second hypothesis was tested using a Pre-test-Post-test Control Group design (Tuckman, 1972, p.110), where the dependent variable was attitude towards geology, the independent variable was type of lab instruction, and the moderator variables were university entrance marks and students' previous geology studies (see Fig. 3). Pre-test and post-test were the same attitude questionnaire, constructed on a Likert scale model, and validated by the author (see p.51) in the pilot project period. Students' university entrance marks and previous studies in geology were again considered as moderator variables in order to examine the effects of prior academic achievement. Assignment of subjects to control and experimental groups was random.

$$R\ O_1 X\ Y^1 Y^2 O_2$$

R = random assignment of subjects.
O_1 = pre-test for dependent variable (attitude towards geology)
X = independent (treatment) variable
  a) individualized audio-visual laboratory instruction only
  b) regular laboratory instruction plus optional audio-visual instruction
  c) regular laboratory instruction only (control)
Y^1 = moderator variable #1 (university entrance marks)
Y^2 = moderator variable #2 (previous studies in geology)
O_2 = post-test for dependent variable

Fig. 3

Research Design - Stage I - Hypothesis 2

5.1.1.2 Stage II Hypotheses

During Stage II of the research, three hypotheses were tested, and these are stated in null form as follows:

a. There will be no difference in test marks between students who received only regular lab instruction during first term, and student who received audio-visual lab instruction in addition to regular lab instruction. Students' university entrance marks and previous studies in geology will have no effect on the results.

b. There will be no difference in attitude towards geology between students who received only regular lab instruction during first term, and students who received audio-visual lab instruction in addition to regular lab instruction. Students' university entrance marks and previous studies in geology will have no effect on the results.

c. There will be no difference in expected grades between students who received only regular lab instruction during first term, and students who received audio-visual lab instruction in addition to regular lab instruction. Students' university entrance marks and previous studies in geology will have no effect on the results.

The following operational definitions were employed:

Audio-visual laboratory instruction: same as Stage I.

Regular laboratory instruction: same as Stage I.

Test marks: average of students' scores on bi-weekly lab tests given during first term, compared with students' scores on the first lab test.

Attitude towards geology: the same attitude questionnaire used in Stage I was re-administered at the end of first term, and students' responses compared with those on the second application of the questionnaire during Stage I.

Expected grades: as indicated by students' responses to an item on the first and final administration of the attitude questionnaire asking whether they expected to receive a grade of A, B, C, or D in the course.

University entrance marks: same as Stage I

Previous studies in geology: same as Stage I

All three Stage II hypotheses were tested using a Pre-test Post-test Control Group design (cf. Fig. 3) with test marks, attitudes towards geology and expected grades as the three dependent variables, type of lab instruction as the independent variable, and university entrance marks and previous studies in geology as moderator variables. The same sample of students from the Geology 010 class were used as were considered in Stage I, but since use of the audio-visual lab material was voluntary during this part of the research, assignment to experimental and control groups was not random.

5.1.2 Geology Department Aims

The answers to the questions posed by the Queen's University Geology Department were, to a large extent, provided by purely formative investigation (e.g. records of lab use, test marks, questionnaire scores, etc.), although the statistical information provided by the experimental portion of the study was taken into consideration as well. This final, formative, investigation will henceforth be referred to as Stage III.

5.1.2.1 Stage III - Research Plan

The "research plan" for Stage III involved an examination of the operation of the audio-visual lab throughout the entire first term (September to December, 1974), and the use made of the lab material by the entire Geology 010 class. Specifically, the evaluation proceeded as follows:

a. Recording the names of all students using the audio-visual lab material, in order to determine overall numbers, and patterns of lab use by class section.

b. Collecting opinions from the students who used the audio-visual material, by means of an opinion questionnaire (designed and validated by the researcher, see page 51), administered at the end of first term.

c. Comparing students' attitudes towards the Geology 010 course, as indicated by responses to the attitude questionnaire given to all students at the end of first term.

d. Collecting opinions from the audio-visual lab demonstrators by means of an open-ended questionnaire given at the beginning of second term.

e. Comparing the average lab marks at Christmas of those students who used the audio-visual lab units in addition to their regular lab classes, and those students who attended regular lab classes only.

f. Assessing the audio-visual lab's effectiveness as a source of review, based on students' comments, test results, and lab demonstrator's comments.

g. Calculating the overall cost of the audio-visual lab.

h. Assessing the feasibility of extending the audio-visual lab, based on the information gathered above.

5.2 Population and Sample

5.2.1 Stage I

The population under consideration was the first year class of Applied Science students registered in Geology 010 (1974-75 enrollment = 366). The University Admissions Office divided these students alphabetically into sections of approximately 40 students, and it is assumed that this assignment was unbiased. Three of these sections were randomly chosen for the experiment. Section A (N = 36) was chosen as the first experimental group, to receive audio-visual lab instruction only, for the first lab class. Section C (N = 41) was chosen to receive regular lab instruction for the first lab class, with the option of additional audio-visual lab instruction in the evenings, if desired. Section G (N = 34) was chosen as the control group, to receive only regular instruction for the first lab class.

5.2.2 Stage II

The population under consideration was the same as that in Stage I. For Stage II of the research, students in Sections A, C and G were again selected as the sample, although the total number of students involved (N = 107) was lower than that in Stage I due to drop-outs and incomplete test data. For Stage II, this sample was divided into two groups, depending on whether or not students had used the audio-visual lab material at any time during the first term. Since use of the audio-visual lab material in Stage II was purely voluntary, assignment of students to "control" (did not use the audio-visual lab) and experimental groups (used the audio-visual lab material in addition to attending regular lab classes) was not random, but reflected students' personal decisions.

5.2.3 Stage III

The sample used for Stage III ~~was~~ the entire population of students registered in Geology 010 (N = 366). Students were divided into two groups, depending on whether or not they had used the audio-visual lab material at any time during the first term. Again, as in Stage II, assignment to these two groups was not random.

5.3 Preparation of Material

Based on the findings of the 1973-74 pilot project, the audio-visual lab material was re-written during the summer of 1974. Although the basic framework and overall objectives of the four lab units remained the same, the following improvements were made:

a. More slides were added to each of the units. Some of these were taken from photographs in books, some from commercial slide sets on rock and mineral identification, and some were prepared by the author. Most of these new slides showed actual rock and mineral formations as they appear in the field. The slides prepared by the author, however, were used to illustrate the different concepts involved in mineral identification (e.g. cleavage and fracture) using specimens taken from the students' trays and photographed under a magnifying lens. All slides were copied by the author using facilities at the Faculty of Education, Queen's University.

b. In the original audio-visual lab units, the exercise whereby students were to identify all the samples in the tray came in the middle of the lab unit. This was then followed by slides of rock outcrops to link the specimens to the larger formations. However, it appeared that most students left the identification procedure until the end of the tape-slide material. Therefore, the structure of all four units was altered to put the identification exercise at the end of the lab unit. In order to ensure that the students had mastered the various concepts involved in the identification procedure before they started this exercise, short one or two-item tests were included within the body of the lab instruction at each step in the identification procedure. Answers to these questions, and to the final identification exercise, were included with the lab notes for each unit.

c. Many parts of the lab material were re-written in conjunction with the Geology Department professors to eliminate ambiguity, and to complement the information to be covered in the lecture portion of the course. In addition, all of the lab notes for the lab course (which were also used with the audio-visual lab instruction) were re-written by the geology professors in order to improve their quality. Master tapes for the revised lab units were prepared by Queen's University Radio Station, CFRC and cassette duplication was done by C.I.T., Concordia University. A copy of the tape script and lab notes for Unit One - Mineral Identification can be found in Appendix C.

d. Five table-top carrels (4' x 2' x 2') were built by the Geology Department, and installed along the rear wall of one of the lab rooms. The carrels were completely painted white, so that one of the interior side walls could be used as a screen. Small boxes (12" x 12" x 4") were built to act as a platform for the slide projector, with room underneath for the tape recorder. Appendix D shows a diagram of one of the carrels.

e. The audio-visual lab opinion questionnaire was prepared for use in Stage III of the research. From the 60 item questionnaire used in the pilot study, the 17 items which correlated most highly with the overall test scores were selected. A sample of this revised questionnaire is found in Appendix E.

f. The geology attitude questionnaire was prepared. A 15-item version of this questionnaire was administered to the 12 students registered in the introductory geology course offered during summer school session at Queen's. The 11 items which correlated most highly with the overall questionnaire scores were selected for the revised questionnaire. A sample of this questionnaire may be found in Appendix F.

g. Tests for each of the lab units (including the test to be used to measure the cognitive effects of different lab instruction in Stage I of the research) were prepared by the Geology Department staff. A sample of the mineral identification test incorporated in Stage I of the research is found in Appendix G. The marking scheme is also indicated.

h. Displays of rocks and minerals were prepared by the Geology Department staff, to be set up in the hallway outside the lab rooms. These displays were designed to illustrate the concepts covered in the lab classes, using specimens from the Geology Department's collections. Reference was made to these displays in the audio-visual lab material, as an additional source of information.

5.4 Instrumentation

5.4.1 Stage I

Stage I of the research project took place from September 23 to October 11, 1974. Whereas in previous years, lab classes were held once a week, with the lab course terminating at Christmas, during the 1974-75 session, it was decided that the lab course should be extended to cover the full two terms by holding lab classes once every two weeks. Stage I of the research extended over the first two weeks of the lab course, but involved only one lab class (Mineral Identification).

Originally, it had been intended to extend the period of experimental comparison to cover the first four lab sessions. With the change in scheduling for 1974-75, however, this would have involved the students for eight weeks - very nearly the whole of the first term. This was felt by the Queen's staff to be unwise, in view of the scheduling problems it would create. There was also much conern expressed that using the Geology 010 class as guinea pigs for such a long period might be unfair to the students. But by far the most important reason for restricting the length of the experimental period was the very success of the audio-visual lab as already established. The Queen's staff felt that the audio-visual facilities were vital for review, and wanted them to be available to all students as soon as possible after the beginning of classes in September. Even had the research experiment involved only two lab sessions, the audio-visual material would still have been unavailable to most of the Geology 010 students until some time in late October.

Therefore, the experimental (Stage I) period was restricted to a two-week period only. According to the Queen's timetable, lectures were to begin on September 16, and lab sessions were to begin the following week, September 23.

The students in Section A (who received audio-visual instruction for their first lab session) were told about the arrangement for their lab instruction during their first lecture class. The word "experiment" was not mentioned. Rather, the students were told that the Geology Department was trying to evaluate different methods of lab instruction, in order to find out what seemed to work best for the students. They were asked to co-operate in this project by using the audio-visual material for their first lab, and giving their comments. Because of the shortage of equipment, students were scheduled, and asked to do their lab work at a specific time of day or evening during the two week period before the second lab class. It was also explained to the students that starting with their second lab class, they would be attending regular lab periods at the time indicated on their timetable.

Section C students were given information about the audio-visual lab material during their first lab class, and told that they could use it for supplementary review or clarification if they wished. Special time slots were made available each evening for the Section C students (so that they would not conflict with the Section A students) and they were asked to use the lab only at those times.

Section G students (the control group) were not told anything about the audio-visual lab material until the Stage I experimental period was over.

At the beginning of the first lab period, students in all three sections were asked to fill out the geology attitude questionnaire. This questionnaire also asked whether students had previously taken a geology or earth sciences course, and what mark they expected to receive in Geology 010. This questionnaire was administered by the lab demonstrators. The Section A students were also asked to fill out a short opinion questionnaire after completing the audio-visual lab material, in accordance with the explanation given to them about the project. The results of this questionnaire were used for information only, and were not incorporated into the research results.

At the beginning of the second lab period (by which time all students were receiving regular lab instruction), students were given a short mineral identification test based on the contents of the first lab. This test was administered and marked by the senior student lab demonstrators and markers. In addition, the geology attitude questionnaire was re-administered (with the questions in a different order, so that it wouldn't look too obvious).

Lab demonstrators for all three sections were fourth year or graduate students in geology. They were chosen by the Geology Department on the basis of their marks, and teaching ability. Sections C and G had two demonstrators, each in charge of half of the group. Section A also had two regular demonstrators, plus five other senior students who took turns running the audio-visual lab each day of the two week experimental period.

5.4.2 Stage II

After the initial two-week experimental period was over, the audio-visual lab material was made available to all students in the Geology 010 class on a voluntary basis. The lab was open four nights a week, from 6:00 p.m. to 10:30 p.m. (These were shorter hours than those used during the previous year, since during the 1974-75 session, there was a longer period of time between lab classes). Because of the limited amount of equipment, students were asked to sign up in advance. Each student was allowed one and one half hours but could spend longer if equipment was free. A fourth year or graduate geology student was on duty in the lab each night to sign out equipment and to answer questions. Students were asked to leave their student identification cards with the lab demonstrator while they were using the audio-visual equipment. This enabled the demonstrator to keep a record of names, and to control pilfering of equipment and specimens.

The Geology 010 students were told about the audio-visual lab material during their second lab class (the week of October 7). In addition, information sheets were handed out by the lab demonstrators, and a poster was put up on the Geology 010 bulletin board outside the lab rooms.

Although there was no mid-term test or Christmas examination in the lab course this year, records were kept of the students' marks on the short tests given at the beginning of each lab class to test students' knowledge of the material covered in the previous lab. These marks were averaged to obtain a Christmas mark.

During their final lab class of first term, all students were asked to fill out a geology attitude questionnaire (the same questionnaire used during Stage I). This questionnaire also asked what grade students expected to receive in Geology 010. The questionnaire was administered by the lab demonstrators.

5.4.3 Stage III

The procedure carried out for the overall evaluation of the audio-visual lab's effectiveness was the same as that described for Stage II.

In addition, however, all students who had used the audio-visual lab material at any time during the first term were asked to complete an opinion questionnaire on the lab, given out during the last lab class of first term. This questionnaire was administered by the lab demonstrators.

The researcher also asked for comments from the lab demonstrators who had operated the audio-visual lab, by means of a short open-ended questionnaire sent out at the beginning of second term. For a sample of this questionnaire, see Appendix H.

Cost figures for the audio-visual lab equipment and lab demonstrators' salaries were obtained from the Geology Department.

5.5. Data Gathering and Statistical Procedures

5.5.1 Stage I

Data for each of the variables considered in Stage I were gathered in the following way:

University entrance marks: Students' university entrance marks were obtained from the Queen's University Office of Admissions. All marks were expressed in percentage form. In the cases where students entered Queen's from outside the province, entrance marks were adjusted, where applicable, by a figure of +10% or -10%, on the advice of the Admissions Office, in order to bring them into line with the Ontario Grade 13 standard.

Previous experience in geology: On the first administration of the geology attitude questionnaire, students were asked to answer "yes" or "no" to the question "Have you ever taken a geology or earth sciences course before?"

Test marks: The students' mineral identification tests were marked, according to a marking scheme designed by the Geology Department staff, by fourth year student markers. Results were expressed in percentage form.

Attitudes towards geology: Scores on each item of the attitude questionnaire were weighted, depending on whether the question was stated in positive or negative form (a response of "strongly agree" could therefore have a raw score of either one or five). A score of five on any particular item indicated a high positive attitude towards geology. Total questionnaire scores were obtained, and the mean score for each student calculated on both applications of the geology attitude questionnaire. In order to determine any shifts in attitude, the difference between these mean scores for each student was then calculated.

Treatment group: Students in Section G were considered as the control group. Students in Section A (audio-visual lab instruction only) were considered as Experimental Group I. Students in Section C (regular lab instruction plus optional audio-visual lab instruction) were considered as Experimental Group II.

The effects of the independent variable (type of lab instruction) and the moderator variables (university entrance marks and previous geology) on each of the two dependent variables (test marks and attitudes towards geology) were examined by multiple regression analysis (see Ferguson, 1971, p.390-404). It had originally been intended to use analysis of variance, but there are a number of difficulties involved in carrying out ANOVA when the treatment groups are of unequal size, and Ferguson (1971, p.264) suggests the use of the least-squares method, which is part of the multiple regression procedure.

The multiple regression formula used was:

$$\hat{Y} = \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots \beta_n X_n + \alpha$$

where $\hat{Y}$ = predicted values of the dependent variable

$X_1 \ldots X_n$ = values of each of the independent variables and moderator variables.

β = the "weight" or proportional effect of the corresponding X value, determined by the method of least squares

α = the constant (performance of the control group)

Using this formula, it was possible to determine the extent to which the independent and moderator variables and their interaction effects) were predictive of the two dependent variables, test scores and attitude shift (at $p = <.05$). A Queen's University WATFOR programme was used, which, in addition to calculating the multiple correlation coefficient for each equation, converted the β-weights to t-values as a test of the significance of each component of the equation, and also carried out analysis of variance on predicted vs. residual values to test the significance of the equation as a whole.

5.5.2 Stage II

Data for each of the variables considered in Stage II were gathered in the following way:

University entrance marks: Same as Stage I.

Previous experience in geology: Same as Stage I.

Test marks: Students' marks in all of the first term lab tests (a total of five) were averaged to obtain a Christmas mark, expressed in percentage form. The difference between the Christmas mark and the mark on the first lab test (Mineral Identification) was calculated, in order to indicate any shifts.

Attitudes towards geology: Scores on the third application of the attitude questionnaire were calculated by the method described previously. Each student's total mean score on the third application of the attitude questionnaire was subtracted from the total mean score on the second application in order to determine shift in attitude.

Expected grade: Students were asked, on the first and final administration of the geology attitude questionnaire (during the first and final lab classes of first term) what grade they hoped to receive in Geology 010 (either A, B, C or D) and what grade they expected to receive (either A, B, C or D). Since there appeared to be little difference between grade hoped for and grade expected, and because the measure was so crude, it was decided to consider only students' expected grades for computer analysis. The responses were given a numerical value of A=1, B=2, C=3, and D=4. The difference between the students' first and second answer was calculated in order to determine any shift in expectation.

Treatment group: Students in Sections A, C and G who did not use the audio-visual lab material at any time during the first term were considered as the control group. Students in Sections A, C and G who had used the audio-visual lab material at least once (excluding the use made of the audio-visual lab by Section A for the first lab session) were considered as the experimental group.

The data were analyzed by multiple regression, as described above in Section 5.5.1, in order to examine the effects of main (independent plus moderator) and main plus interaction variables on each of the three dependent variables (shift in test marks, shift in attitude, and shift in expected marks).

5.5.3 Stage III

Data pertaining to each of questions stated in Chapter 4, Section 4.2 were gathered in the following way:

Student use of the audio-visual lab: Students' names and section numbers were recorded in a notebook by the lab demonstrator.

Students' opinions of the audio-visual lab: Scores on each of the items on the audio-visual lab opinion questionnaire were weighted, depending on whether the question was stated in positive or negative form, so that a high score indicated a high positive attitude. Mean scores were calculated for each questionnaire and combined to obtain mean scores for each section of the Geology 010 class.

Lab demonstrators' opinions: The replies to the questions on the lab demonstrators' questionnaire were summarized and presented in descriptive form.

Student attitudes towards geology: Individual mean scores on the attitude questionnaire were calculated, as already described. These were combined to present mean scores for each section of the class, and mean scores for those students who did and did not make use of the audio-visual lab material.

Christmas marks; Christmas marks were obtained for all students in Geology 010 by averaging the marks on the five lab tests given during the first term. These marks were combined to obtain mean Christmas marks for each of the sections of the class, and mean scores for those students who did and did not make use of the audio-visual lab material during first term. A t-test was carried out to compare the mean Christmas lab marks for the two groups of students.

Cost figures: Prices of the audio-visual lab equipment were obtained from the Geology Department, as well as total salary paid to the audio-visual lab demonstrators. In addition, an estimated monetary value for the author's time was calculated.

With the exception of the Christmas lab marks, none of the foregoing data underwent statistical analysis, but were presented purely as described above.

5.6 Experimental Constraints

Before considering the results of the research, it would be useful to examine the kinds of constraints within which the project was carried out, and the implication of these constraints for future research.

Educational research often seems to fluctuate between two extremes. On one hand, there is the kind of carefully controlled "laboratory"-like experiment in which all variables are regulated solely by the experimenter. The drawback of this particular variety of educational research is that it often says a great deal about laboratory conditions, and very little about classrooms in real educational institutions.

The other extreme, however, in which educational theories are tried out in classroom conditions with no attempt to control the environment at all, is apt to tell us a fair amount about the teacher, and something about the students' likes and dislikes, but can provide little factual information about the instructional system itself that could be applied to other situations.

The present research project has attempted to avoid both extremes. It has, on one hand, tried to test a different method of instruction within an existing university course, without creating an artificial "experimental" environment. On the other hand, it has tried to control for some of the major sources of bias by using randomly selected groups were possible, and by comparing experimental group results with a control group. It has tried to isolate the differing effects of experimental treatment, prior experience in the subject, and students' academic level. Furthermore, it has tried to keep separate the laboratory instruction for each of the three groups considered in Stage I, in terms of time and physical space -- no mean feat in a course with a rigid timetable and an initial enrollment of over 400.

However, there were several factors which could not be controlled without removing the experiment entirely from the Geology 010 course. To begin with, the researcher had no control over the lab demonstrators assigned to the various sections. Thus, each of the three sections considered in

Stage I had two different demonstrators. Likewise, the senior students marking the unit tests were different for each section, although they all used the same pre-set marking scheme. In addition, each section had a different professor handling the twice-weekly lectures. It is evident, therefore, that the Stage I research was open to bias from instrumentation.

Likewise, in Stage II, random selection of the experimental group was not possible, since students' use of the audio-visual material was entirely voluntary. In addition, the effects of history and instrumentation over the first term period could not be controlled or accounted for.

The above-mentioned threats to the validity of the research should not be taken to imply that any results obtained are worthless. Rather, they should be seen as the constraints within which the research was carried out -- constraints imposed by the course itself, and by the administrative decisions made by Queen's University. They are indicative of the kinds of constraints surrounding any kind of ongoing classroom evaluation. Elimination of these constraints would be to eliminate the value of a real-life educational testing environment. Nevertheless, statistical results obtained in this kind of environment cannot be taken as hard and fast absolutes, but rather as indications of overall trends, relative to the factors which could not be controlled. If many different kinds of data are gathered, and compared with each other, an overall evaluation should be possible which, although perhaps not statistically significant at the $p = <.05$ level, would nonetheless be able to answer the questions asked at the outset of the experiment. Applied research, after all, should be primarily concerned with providing the basis for sound decisions. While the clarification of scientific hypotheses is important, it should not be the only yardstick for evaluating the success of educational research.

CHAPTER VI

RESULTS

6.1 Stage I

The data gathered during the two-week controlled experimental period are presented in descriptive form in Table 1. It can been from this table that the Section A students had a higher overall university entrance level, although all three groups had roughly the same proportion of students with previous geology courses to their credit. In the first lab test (Mineral Identification), Sections A and G scored equally well, although Section C students scored an average of 20% less. Section A students had a slightly more positive attitude towards the course at the beginning of classes, but all three groups dropped in their estimation of geology after two weeks.

Multiple regression analysis was carried out on both dependent variables (test scores and attitude shift) to examine the main and main plus interaction effects, with a significance level of $p=<.05$ as the standard. The results of this analysis are presented in Tables 2,3,4 and 5.

Table 2, which shows the effects of the main variables on students' scores on the first lab test, indicates two factors statistically significant at the $p =<.05$ level. First of all, students' university entrance marks were highly predictive of their subsequent scores on the first lab test (p = <.001). The second significant factor can be deduced from the descriptive data; that is, that students in Section C did much worse on the first lab test than students in the control group (p= <.001). In other words, the type of lab instruction used with Section C students (regular lab instruction plus the option of additional audio-visual lab instruction) seems to have had a negative effect on students' test performance. There were several external factors which could have accounted for this effect, however, and these will be discussed later.

Table 3, which examines main plus interaction effects in relation to students' scores on the first lab test shows that interaction effects dissipate the two significant factors indicated in Table 2, without themselves being significant at the acceptable level.

Tables 4 and 5 examine the effects of main plus interaction variables on the second dependent variable (attitude shift over the two-week experimental period). None of the variables considered were predictive of the attitude shift in any significant way.

6.2 Stage II

The data collected on the students in Sections A, C and G over the entire first term period are presented in descriptive form in Table 6. Those students who used the audio-visual lab material had a slightly higher university entrance level than those students who attended only the regular labs.

Table 1

Descriptive Data - Stage I

Group	Number	university entrance Marks	% students with previous geology	Mineral ID score	Attitude Q.#1 Mean score	Attitude Q.#2 Mean score	Attitude shift
G[a]	34	76.44	15	80.09	3.34	3.30	-.04
A[b]	36	80.03	22	79.22	3.75	3.68	-.07
C[c]	41	77.49	15	58.22	3.40	3.22	-.18

Note:- Each group followed a lecture course concurrently.

[a] Control group -- regular lab instruction only

[b] Experimental group #1 - audio-visual lab instruction only

[c] Experimental group #2 - regular lab instruction plus optional audio-visual

Table 2

Multiple Regression Analysis - Stage I

Relation of: a) previous geology courses to test scores (d.v.).
b) university entrance marks
c) type of lab instruction

	Source	t-value
1.	Previous geology courses	-0.386
2.	University entrance marks	3.535*
3.	Section A[a]	-0.874
4.	Section C[b]	-6.450*

Multiple $R^2 = 0.379$

Note:- All t-values are relative to those of the control group (Section G) which is the constant.

[a] Audio-visual lab instruction only.

[b] Regular lab instruction plus optional audio-visual.

* p= <.001

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	14557.6	4	3639.4	16.156
Residual	23878.0	106	225.26	
Total	38453.6			

Table 3

Multiple Regression Analysis - Stage I

Relation of: a) previous geology courses to test scores (d.v.)
b) university entrance marks
c) method of lab instruction
d) interaction effects

	Source	t-value
1.	Previous geology courses	-0.537
2.	University entrance marks	1.585
3.	Section A[a]	-1.029
4.	Section C[b]	-0.900
5.	Interaction, 2 x 3	0.938
6.	Interaction, 2 x 4	0.156

Multiple $R^2 = 0.385$

Note:- All t-values are relative to those of the control group (Section G) which is the constant.

[a] Audio-visual lab instruction only.

[b] Regular lab instruction plus optional audio-visual.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	14783.0	6	2463.83	10.833
Residual	23652.6	104	227.429	
Total	38435.6			

Table 4

Multiple Regression Analysis - Stage I

Relation of: a) previous geology courses to attitudes (d.v.).
b) university entrance marks
c) method of lab instruction

	Source	t-value
1.	Previous geology courses	1.064
2.	University entrance marks	-0.135
3.	Section A[a]	0.557
4.	Section C[b]	-0.882

Multiple $R^2 = 0.033$

Note:- All t-values are relative to those of the control group (Section G) which is the constant.

[a] Audio-visual lab instruction only.

[b] Regular lab instruction plus optional audio-visual.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	.280929	4	.070232	0.908
Residual	8.19800	106	.077339	
Total	8.47893			

Table 5

Multiple Regression Analysis - Stage I

Relation of: a) previous geology courses to attitudes (d.v.).
b) university entrance marks
c) method of lab instruction
d) interaction effects

	Source	t-value
1.	Previous geology courses	0.964
2.	University entrance marks	-0.935
3.	Section A[a]	-0.890
4.	Section C[b]	-0.967
5.	Interaction, 2 x 3	0.960
6.	Interaction, 2 x 4	0.873

Multiple $R^2 = 0.044$

Note:- All t-values are relative to those of the control group (Section G) which is the constant.

[a] Audio-visual lab instruction only.

[b] Regular lab instruction plus optional audio-visual.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	37011	6	.061685	0.791
Residual	8.10882	104	.077969	
Total	8.47893			

This is further reflected in the scores on the first lab test, where those who later used the audio-visual lab in addition to attending regular lab classes started off at a higher level than those students who attended regular lab classes only, during first term. Both groups of students dropped slightly in standing by the time their Christmas averages were calculated. Surprisingly, in this sample, the students who used the audio-visual lab materials during first term dropped more than those who did not use the audio-visual lab, although the former group still had a higher average mark than the latter. Students who used the audio-visual lab material during first term had a more positive attitude towards geology as of the second lab class, but by Christmas, those students who used the audio-visual lab during first term had lowered their opinion of the course, while those students who had not used the audio-visual lab material showed a slight increase in positive attitude towards the course.

Students in both groups showed a drop in expected marks between September and December. Both groups, on the average, expected a mark between B and C by December, although the students who used the audio-visual lab had started out with higher expectations than the others.

The above data were examined by multiple regression analysis, to determine the extent to which main and main plus interaction variables were predictive of each of the three dependent variables (shift in test marks between October and December, shift in attitudes towards geology between October and December, and shift in expected marks between September and December). The results of this analysis are presented in Tables 7,8,9,10,11 and 12.

The difference in marks between the first lab test and the Christmas average was not significantly affected by any of the variables examined, as can be seen in Tables 7 and 8. Interaction effects were also found to be negligible.

Table 9 shows the effects of main variables only on the shift in students' attitudes towards geology between October and December. Although the descriptive data indicated that students who used the audio-visual lab during first term had a more negative attitude towards the course after three months, this effect was not significant at $p = <.05$. Interaction effects also failed to reach the required level of significance, or to improve the prediction of students' attitudes towards geology(Table 10).

The effects of main variables on the shift in students' expected marks are shown in Table 11. Here, it is to be remembered that a positive t-value indicates a negative relationship, since expected grades were scored A=1 and D=4. None of the main variables are predictive of students' expected grades at $p =<.05$. However, when interaction effects are taken into consideration (Table 12), university entrance marks appear negatively related to expected grades ($p= <.05$).

Table 6

Descriptive Data - Stage II

Group	N	% with prev. geology	Univ. ent. marks	Mineral ID score	Xmas avge.	Att.Q#2 mean score	Att.Q#3 mean score	Expctd. mark #1[a]	Expctd. mark #2
Experimental[b]	66	17	79.97	73.77	73.30	3.35	3.12 N=53	2.09 N=54	2.41
Control[c]	41	19	75.46	71.27	71.36	3.25	3.28 N=30	2.29 N=31	2.42

[a] A=1; B=2; C=3; D=4

[b] Students who used a-v lab during first term, in addition to attending regular lab classes.

[c] Students who attended regular lab classes only, during first term.

Table 7

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to test marks (d.v.).
b) university entrance marks
c) use of a-v lab

	Source	t-value
1.	Previous geology courses	1.203
2.	University entrance marks	-0.010
3.	Use of a-v lab material during first term.[a]	-0.078

Multiple $R^2 = 0.014$

Note:- All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] excluding the use made of the a-v lab material by Section A students during Stage I.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	286.766	3	95.588	0.487
Residual	20197.8	103	196.095	
Total	20484.5			

Table 8

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to test marks (d.v.).
b) university entrance marks
c) use of a-v lab
d) interaction effects

	Source	t-value
1.	Previous geology courses	.657
2.	University entrance marks	.177
3.	Use of a-v lab material during first term[a]	.242
4.	Interaction, 1 x 3	.159
5.	Interaction, 2 x 3	-.260

Multiple $R^2 = 0.015$

Note:- All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] excluding the use made of the a-v lab material by Section A students during Stage I.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	306.059	5	61.211	0.306
Residual	20178.5	101	199.787	
Total	20484.5			

Table 9

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to attitudes (d.v.).
b) university entrance marks
c) use of a-v lab

	Source	t-value
1.	Previous geology courses	.351
2.	University entrance marks	-0.868
3.	Use of a-v lab material during first term.[a]	-1.928

Multiple $R^2 = 0.066$

Note: All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] excluding use made of the a-v lab material by Section A students during Stage I.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	.8798	3	.29329	1.848
Residual	12.5379	79	.15870	
Total	13.4178			

Table 10

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to attitudes(d.v.).
b) university entrance marks
c) use of a-v lab
d) interaction effects.

	Source	t-value
1.	Previous geology courses	1.391
2.	University entrance marks	-1.064
3.	Use of a-v lab material during first term.[a]	-1.029
4.	Interaction, 1 x 3	-1.648
5.	Interaction, 2 x 3	-0.892

Multiple $R^2 = 0.107$

Note:- All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] excluding use made of the a-v lab material by Section A students during Stage I.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	1.4344	5	.28688	1.843
Residual	11.9833	77	.15562	
Total	13.4178			

Table 11

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to expected grades (d.v)
b) university entrance marks
c) use of a-v lab

	Source	t-value
1.	Previous geology courses	0.706
2.	University entrance marks	1.788
3.	Use of a-v lab material during first term.[a]	0.913

Multiple $R^2 = 0.060$

Note:- All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] excluding use made of the a-v lab material by Section A students during Stage I.

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	3.1699	3	1.0566	1.744
Residual	49.6789	82	.6058	
Total	52.8488			

Table 12

Multiple Regression Analysis - Stage II

Relation of: a) previous geology courses to expected grades (d.v)
b) university entrance marks
c) use of a-v lab
d) interaction effects

	Source	t-value[a]
1.	Previous geology courses	1.565
2.	University entrance marks	2.316*
3.	Use of a-v lab material during first term[b]	1.514
4.	Interaction, 1 x 3	-1.282
5.	Interaction, 2 x 3	-1.351

Multiple $R^2 = 0.097$

Note:- All t-values are relative to those of the control group (students who did not use the a-v lab material during first term) which is the constant.

[a] because expected grades were scored A=1 and D=4, positive t-values indicate negative relationships.

[b] excluding use made of the a-v lab material by Section A students during Stage I.

* p= <.05

Analysis of Variance

Source	Sum of Squares	df	Mean Square	F
Regression	5.15046	5	1.03009	1.728
Residual	47.6983	80	.59622	
Total	52.8488			

6.3 Stage III

Data on the use made of the audio-visual lab material by the entire class of Geology 010 during the first term are presented in Table 13. Here, it can be seen that 53% of the total class used the audio-visual lab material at least once (excluding the use made of the audio-visual lab by Section A students during Stage I of the research). This is an impressive figure, given that the audio-visual lab material was supplementary to the regular lab classes, and available purely on a voluntary basis. Judging by the fact that the audio-visual lab was filled to capacity nearly every night, this figure would have probably been higher had the lab been open more often.

During the final lab class, students who had used the audio-visual lab at any time during first term (again, excluding Section A during Stage I), were asked to fill out a 17-item questionnaire to determine what they thought of the audio-visual lab units. These results are summarized in Table 14. The average mean score for the entire group was 3.66 (on a five-point scale) which represents a generally positive attitude. It is interesting to compare these scores with the same students' scores on the geology attitude questionnaire (Table 15). In all cases, students' opinions of the audio-visual lab material were higher than their opinions of geology as a whole. For a breakdown of students' responses to each question of the audio-visual opinion questionnaire, see Appendix I.

Table 15 compares the geology attitude test scores at Christmas of students who had and had not used the audio-visual lab material during the first term. Students who had used the audio-visual lab had a more positive attitude towards the course than those who had not used the audio-visual lab material at all, but in the light of the data presented in Tables 9 and 10, it is impossible to assume that students who used the audio-visual lab had, in fact, improved their attitude towards the course between September and December.

Table 16 summarizes the comments made by the seven lab demonstrators who ran the audio-visual lab during the first term. On the whole, the demonstrators thought that the audio-visual lab was a very useful addition to the Geology 010 course, and made several good suggestions for its improvement next year.

Students' marks, at the beginning of the term and at Christmas, are compared in Table 17. At Christmas, students who had used the audio-visual lab material during the term averaged 8.99% above students who had not used the audio-visual lab at all. However, students in the former group had averaged 7.58% higher even at the beginning of the term so the presumed effects of the audio-visual lab material may appear to be negligible. However, when a t-test was carried out to compare the average Christmas lab marks of those who had used the audio-visual lab during first term and those who had not, according to section, it was found that in Sections B, C, E/J, and H students who had used the audio-visual lab had significantly higher test marks (p =<.05) than students who had attended regular lab classes only. Therefore, it would appear that the use of the audio-visual lab material did have a definite effect on students' test marks during first term.

Finally, a breakdown of the costs involved in setting up and running the audio-visual lab is presented in Table 18. The researcher was unpaid, but an estimated salary was calculated and will be discussed later.

In summary, then, Stage I of the research found that students' university entrance marks were highly predictive (p=<.001) of scores on a cognitive test, and that students receiving regular plus optional additional audio-visual lab instruction for the first lab class scored lower (p=<.001) on the first lab test than students in the other two groups. None of the variables examined were predictive of students' attitude towards geology. Stage II found that none of the variables examined were significantly related (p=<.05) to either lab test marks, or attitudes towards geology at the end of first term. Students' university entrance marks were negatively related (p =<.05) to expected marks at the end of first term. Stage III found that 53% of the Geology 010 students used the audio-visual lab at least once during first term, and students had a positive attitude towards this method of instruction. Use of the audio-visual lab does not appear to have improved students' attitude towards geology, but in four of the eight sections, students who had used the audio-visual lab in addition to attending regular lab classes, scored significantly higher (p=<.05) on their lab tests during first term.

Table 13

Stage III - Numbers Using A-V Lab Material During First Term

Section	Number in Section	No. of Times A-V Lab Used					Total	% of Class
		1	2	3	4	more than 4		
A[a]	44	15	5	7	2	-	29	66
B	37	5	4	4	1	2	16	43
C	48	16	4	5	1	-	26	54
D	53	6	4	5	3	-	18	34
E/J	46	11	10	5	6	1	33	72
F	43	9	8	3	2	2	24	56
G	46	13	9	2	2	1	27	59
H	49	7	9	4	1	-	21	43
TOTALS	366	82	53	35	18	6	194	53

[a] excluding the use made of the audio-visual lab by Section A students during Stage I (the first lab class).

Table 14

Stage III - Students' Opinions of A-V Lab[a]

Section	No. of completed Questionnaires	Mean Score[b]
A	22	3.66
B	16	3.66
C	19	3.72
D	4	3.66
E/J	30	3.70
F	13	3.55
G	21	3.73
H	20	3.57
TOTALS	145	3.66

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[a] For a breakdown of students' responses to each question on the a-v lab opinion questionnaire, see Appendix I.

[b] using a five-point Likert scale.

Table 15

Stage III - Students' Attitudes Towards Geology at the End of First Term

Section	No. of Questionnaires	Mean Score on Attitude Q'aire[a]	
		A-V Users	Non-Users
A	26	3.55	3.08
B	32	3.27	3.62
C	42	3.12	3.11
D	24	3.14	2.94
E/J	38	3.54	3.27
F	32	3.23	2.63
G	35	3.14	3.42
H	40	3.22	2.72
TOTALS	269	3.30	3.06

[a] using a five-point Likert scale.

Table 16

Stage III - A-V Lab Demonstrators' Opinions (N=7)[a]

1. Proportion of questions from a-v and non a-v students:

Equal numbers of questions:	3
More questions from non a-v students:	4

2. Was one demonstrator sufficient?

Yes:	5
No:	2

3. Did the a-v lab material clear up students problems?

Yes:	6
Unsure:	1

4. Differences in kinds of questions asked by a-v and non a-v students:

No difference:	4
More basic questions from non a-v students:	3

5. Were you able to control pilfering?

Yes:	3
Not altogether:	4

6. Suggestions for improvement:

   Separate rooms for a-v and non a-v students; feedback from markers about students' weaknesses; more slides and/or duplicate specimens to illustrate mineral variations; better lighting in carrels; longer hours.

7. Overall comments:

   "Students thought they were excellent"; "very successful initial attempt at a-v geology"; definitely worthwhile";"a-v labs used mostly by students who didn't really need them (i.e. 'good' students)".

[a] See Appendix H for a copy of the actual questionnaire used.

Table 17

Stage III - Students' Marks on Lab Tests

Section	Number	Avge. Mark on 1st Lab Test		Avge. Term Lab Mark		
		A-V Users[a]	Non-Users	A-V Users	Non-Users	
A	43	78.93	76.93	78.69	75.97	
B	37	58.46	57.63	60.26	50.84	*
C	46	62.92	52.79	69.08	60.06	*
D	52	39.56	42.03	60.40	53.27	
E/J	44	45.50	36.55	66.51	56.53	*
F	42	48.15	37.95	58.96	51.92	
G	44	80.11	79.24	74.20	71.44	
H	46	64.70	55.78	74.14	61.94	**
TOTALS	354[b]	61.13%	53.55%	68.54%	59.22%	

[a] students who used the a-v lab during first term(i.e. after the first lab test)

[b] complete test data not available for entire class of 366

* difference between term lab marks for the two groups significant at p=<.05

** difference between term lab marks for the two groups significant at p=<.001

Table 18

Stage III - Cost of Audio-Visual Laboratory

	Unit Price	Total
Equipment and Materials		
5 Kodak Carousel slide projectors	$125.00	$625.00
5 Sony tape recorders	105.30	526.50
5 Earphones	7.50	37.50
5 Tabletop carrels		99.00
20 Tape cassettes (30 minutes)	1.65	33.00
3 Reel-to-reel tapes (1200 ft.)	4.75	14.25
20 Rolls colour slide film (20 X)	3.21	64.20
Salaries		
Lab demonstrators (total 152.25 hours)	4.50 per hr.	685.00
Preparation Costs		
Master tapes (5 hours, CFRC)	5.00 per hr.	25.00
Cassette duplication (C.I.T., SGWU)		25.00
TOTAL		$2,134.45

CHAPTER VII

DISCUSSION AND CONCLUSIONS

7.1 Stage I

Did the audio-visual lab instruction improve students' scores on a cognitive test (the first lab test)?

The individualized audio-visual lab instruction did not appear to affect students' scores on the Mineral Identification test. The only variable that did predict students' scores on the first lab test was university entrance marks, and this finding is hardly novel. Neither of the two experimental groups did as well on the first lab test as the control group, although the difference between Group G and Group A was very slight (see Table 1). Section C students, who had regular lab instruction, plus the option of additional audio-visual lab instruction, did much worse on the first lab test than the other two groups (p=<.001).

There are a number of factors which may account for this. First of all, since only a handful of Section C students (five out of the class of 41) took advantage of the additional audio-visual lab instruction before the first test, it seems safe to discount the effect of the audio-visual lab instruction as a contributing factor to Section C's poor performance. Several other factors may have affected the test scores. For example, Section C had different lab instructors than either of the two other sections. In addition, Section C had a different professor handling the lecture part of the course, and a different marker for the lab tests. The personalities and instructional abilities of any of these people may have had an effect on Section C's test scores.

Furthermore, although the marking scheme for the first lab test was fairly straightforward, considerable variation was found in the different markers' interpretations of that marking scheme. Section C had a particular problem in that there was a mistake in the marking scheme for its test samples, and all of the Section C papers had to be recalled and remarked. Although this raised the test marks in all cases, it still left them considerably below the marks of the other two sections. It is also conceivable that the ten specimens used for Section C's test were harder to identify than the ten samples used for Section A and ten samples for Section G (different sets of test samples were used to prevent cheating).

Problems of this kind could have been eliminated, or at least controlled, by assigning the same lab instructor to all three test sections, the same professor to the lectures, the same marker for the test papers, and the same samples for the tests. Given the rigid timetable for the first year Applied Science students, and the shortage of lab demonstrators and professors, this would have been clearly impossible without seriously disrupting the course, and unbalancing the teaching loads. Unfortunately, technological research must commonly cope with such difficulties.

The inconclusive results of this part of the experimental analysis, then, indicate the difficulties of carrying out laboratory-pure educational research within an existing educational setting. Still, it is important that the attempt be made, and a compromise be found between controlled laboratory research and descriptive classroom data.

Did the audio-visual lab instruction improve students' attitudes towards geology as a whole?

It appears from the data that the type of lab instruction used during the first two weeks of the lab course had no effect on students' attitudes either one way or the other. Students in all three groups were less enthusiastic about the course after two weeks, although it is difficult to make generalizations about attitude shift after such a short period of time. Perhaps such a drop in attitude is a natural phenomenon in university courses, but it was beyond the scope of this study to try to determine this.

7.2 Stage II

Did audio-visual lab instruction, in addition to regular lab instruction, improve students' lab test marks over the first term?

Use of the audio-visual lab material during first term did not appear to be related to the lab test marks of the student sample. Neither did students' university entrance marks, or any previous geology courses that students might have taken. Students who used the audio-visual lab material during first term tended to have higher marks to start with, even before they used the audio-visual lab material, which would tend to support the popular assumption that only bright, or highly-motivated students make use of auxiliary learning materials. It should be noted, however, that the results obtained from the 107 students in the Stage II test sample were not the same as those obtained in Stage III when the entire class was considered. Nor were they the same as the results obtained during the 1973-74 pilot study (see Chapter III, Section 3.2). In both of the latter cases, it was found that students who used the audio-visual lab material did achieve higher test marks than students who attended regular lab classes only.

Did audio-visual lab instruction, in addition to regular lab instruction, improve students' attitudes towards geology over the first term period?

It appears that there was no relationship between use of the audio-visual lab material and students' attitudes towards geology. University entrance marks and previous geology courses also had no effect on students' attitudes.

The lack of findings with respect to attitudes in both Stage I and Stage II of the research may have been the fault of the testing instrument. The questionnaire used was devised by the author, since no existing questionnaire models to test this type of attitude could be found. The questionnaire items were validated using a very small sample (see p.51).

and it is conceivable that the final test was not a reliable measure of student attitudes towards geology. In addition, the pre-test, post-test experimental model used required the administration of the same questionnaire to the same students at three different times during first term. Many students objected to this, and thus their responses may not have been completely reliable.

Did audio-visual lab instruction, in addition to regular lab instruction, raise the marks that students expected to receive in the course?

The use of the audio-visual lab material does not seem to have affected students' expectations in this respect either one way or the other. However, statistical analysis showed that students with high university entrance marks showed a greater drop in expected marks between September and December than other students ($p=<.05$). This is not really a surprising finding. Students who have done well in high school may expect to do well at university too, but are often rudely surprised by their first contact with university work.

7.3 Stage III

How many students used the audio-visual lab material?

Out of a total class of 366 students, 194 students (or 53% of the class) used the audio-visual material at least once (excluding the use made of the audio-visual lab by Section A students during Stage I of the research). Of these, 112 returned to complete two or more audio-visual lab units. It is probable that more students would have used the audio-visual lab had it been open more often, or upon demand. As it was, students were asked to sign up in advance to use the lab, and the equipment was used to full capacity nearly every night that the lab was open. It seems, then, that the audio-visual lab was no white elephant.

It should be noted here that anywhere from five to twenty additional students per night took advantage of the lab room being open and a demonstrator being on duty to come in and examine the specimen trays. Thus, the audio-visual lab room enabled an even greater number of students to do supplementary review work.

It is interesting to note in Table 13 that the section making most use of the audio-visual lab material was Section E/J. This section is largely made up of students repeating their year, or students who have transferred from another university. In other words, the students in this section have particular learning needs not common to the other sections, and it seems, from the amount of time that Section E/J students spent in the audio-visual lab, that the audio-visual material helped fill some of those needs.

It is also worth noting that Section A students, who had all received audio-visual instruction for their first lab class, continued to make frequent use of the audio-visual lab material during first term. It would seem, therefore, that Section A students were favourably impressed by their first contact with the audio-visual lab.

What did the students think of the audio-visual lab material?

Almost without exception, the 145 students who filled out the audio-visual lab opinion questionnaire expressed a positive attitude. Group mean scores are shown in Table 14, and again, it is noted that Section E/J's score is one of the highest.

In general, students agreed very positively that the audio-visual lab material was useful for review, and helped clarify concepts that were hard to understand. There was some agreement that the audio-visual lab units were preferable to the regular lab classes, but many students were unsure. Students said that they liked this way of presenting geology, and would recommend that everybody in the class use the audio-visual lab material. Responses to each question on the opinion questionnaire are summarized in Appendix I.

The most common reasons stated for using the audio-visual lab units were to study for the bi-weekly tests, and to clarify points that were causing confusion.

Students were also asked to state their overall opinion of the audio-visual lab material, and to give suggestions for improvement. The following is a sample of their comments:

- A good way to learn about the material. Clear and easy to figure out.

- The a-v labs were quite useful and helped to place the rocks in proper perspective by showing them in natural surroundings and by looking at a sample.
- I don't like machines, but they are a necessary evil!
- Good for clarification and review after a lab explanation. Poor if used without lab demonstrator.
- If I hadn't gone to the a-v labs, I would have failed the tests.
- At times they seemed to be a little irrelevant, and were often pretty slow moving.
- It did improve my knowledge. It was like a lecture you can turn back to the things you may have missed.
- Great! Have more of them so more people can use them.

Did students who used the audio-visual lab material during first term have a more positive attitude towards geology as a whole at Christmas?

Students who used the audio-visual lab material did have a slightly higher mean score on the Christmas attitude questionnaire than students who had attended only regular labs. However, the difference was not great, and neither group expressed strong positive attitudes. Whether or not the students who used the audio-visual material had improved their attitude as a result of their supplementary lab work during the term is impossible to determine. Again, flaws in the questionnaire used may have accounted for the inconclusive results.

What did the audio-visual lab demonstrators think of the audio-visual lab?

The seven demonstrators all thought that the audio-visual lab material was a very useful addition to the Geology 010 course. They also noted that the audio-visual lab material seemed to answer many of the students' questions. The students using the audio-visual lab material seemed to ask fewer questions of the demonstrator, and their questions indicated a greater understanding of the material than those asked by students who had not used the audio-visual lab units.

A summary of the demonstrators' comments is found in Table 16.

Did the audio-visual lab material help students get higher marks on their lab tests?

It appears from the data presented in Table 17 that the audio-visual lab material did give students an advantage in their first term lab marks. In Sections B, C, E/J and H students who had used the audio-visual lab material in addition to attending regular lab classes during first term, averaged significantly higher ($p = < .05$) in term lab test marks than students who attended regular lab classes only. This finding is similar to the 1973-74 pilot project results (see Chapter III, Section 3.5.2).

How effective is the audio-visual lab as a source of review?

The answer to this question seems very clear. The mere fact that so many students used the audio-visual lab material for this very purpose is proof of its perceived value as a mode of review. In addition, comments from students and lab demonstrators almost unanimously agree that the audio-visual lab material is useful in this respect. Several students remarked on their questionnaires that they would not have passed the bi-weekly lab tests without the audio-visual material.

In more practical terms, the audio-visual lab allowed students to review outside of regular class time, thus eliminating the need for special "review" classes. Furthermore, the benefits of the audio-visual lab were not limited to those students who were actually using the audio-visual material. Many additional Geology 010 students took advantage of the fact that the lab room was open and a demonstrator on hand to come and examine the specimen trays and ask questions.

The effectiveness of the audio-visual lab was also greatly improved by the new system of bi-weekly lab classes and tests which replaced the old system of weekly labs with mid-term and final Christmas examinations. Students had two weeks to review between each lab class this year, and this spread out the numbers using the audio-visual material, and enabled students to use all of the audio-visual units if they wished.

Thus, the lab facility itself, plus the audio-visual material, seem to have filled the need for a source of review that was outlined in Chapter III of this study.

How much did the audio-visual lab cost?

The capital cost of the audio-visual lab was $1449, as shown in Table 18, although because of the $1000 grant from the Arts and Sciences Faculty, the actual cost to the Geology Department was well below that figure. Now that the major items of hardware have been purchased, yearly running costs should be quite low, with salaries to lab demonstrators being the major item of expense. In terms of materials required, it would be very inexpensive to expand the number of lab units presently available.

There are, however, hidden costs not included in this table. The researcher was not paid for the work involved in preparing, writing, implementing and testing the audio-visual lab. Under normal circumstances, however, an instructional technologist hired to do this work would have cost the Geology Department at least another $4000 (four months at $1000 a month). This expense could be avoided by having Geology staff members prepare the audio-visual units themselves, but in terms of time and salary cost, this is usually out of the question.

The preparation of any individualized instruction, even on such a small scale as that of the present study, is extremely time-consuming, and this expense is generally the major stumbling block, and the greatest drawback to this type of instruction. Universities such as McGill and Concordia have instructional technology departments that provide personnel and technical facilities to departments wishing to prepare individualized instruction, but even then, the professor in charge of the course must be prepared to devote several months of concentrated effort to the project. Queen's, however, lacks an instructional technology department, and it would probably be impossible for the Geology Department to convert the entire Geology 010 lab class to the audio-visual format without hiring outside personnel, at considerable expense.

It thus seems likely, from the point of view of the time and budget available, that the Geology 010 audio-visual lab will continue only as a supplementary learning resource, with small additions being made if professors can spare sufficient time.

What should be the role of the audio-visual lab in the future?

Since both descriptive and statistical data indicated that the audio-visual mode of lab instruction in itself was no better or no worse than regular lab instruction, in terms of students' marks and students' attitudes towards the course, there seems little point in pursuing the notion of replacing the regular lab with the audio-visual format.

In addition, the amount of time involved to carry out such large-scale expansion is probably beyond the capabilities of the Geology Department staff, as pointed out above.

The results of this study indicate that the real value of the audio-visual lab lies in the opportunity it provides for review <u>in addition to</u> regular lab instruction, and it therefore seems logical to continue to use the audio-visual lab material as a supplementary learning resource. Because of the great demand from the students, it would be a good idea to make it more widely available by extending the lab's hours of operation and/or increasing the number of carrels available. This latter course, however, would require the purchase of additional sets of equipment, and the preparation of additional copies of the instructional material, Thus it might not be feasible financially.

It had been hoped this year to extend the audio-visual material by preparing one or two units on geological structures. However, none of the members of Queen's staff had time to write the lab scripts, so nothing further was done. Again, it seems obvious that the time involved in preparing audio-visual lab material will probably be the largest single factor standing in the way of future extensions of the audio-visual lab. If the Geology Department professors value the audio-visual lab's contribution to the course, yet are unable to extend it themselves, they should probably think of hiring someone on a short-term basis, purely to look after the preparation of the audio-visual lab units. A senior geology student, for example, could do this during the summer, with occasional assistance from the professors in charge of the course. Such a project might also be undertaken by senior geology students as part of their course work, for credit from the University. It is simply too much to ask of professors, already burdened with course teaching, that they tackle this kind of undertaking as well.

CHAPTER VIII

SUGGESTIONS FOR FUTURE RESEARCH.

One of the main areas which the researcher wished to investigate in this study was the effect of differing modes of instruction on students' overall attitudes towards the course, especially since very little had been done in this area to date. The research, however, failed to uncover any such effects. One possible conclusion to draw is that no effects exist -- that is, that different modes of instruction do not affect students' overall opinions of the course. However, it is more likely that the testing instrument itself was at fault, and it is in this area that a great deal of research needs to be done.

First of all, the attitude questionnaire used was completely devised by the researcher, since no ready-made (and previously validated) attitude questionnaire of this type existed. Thus, although the questionnaire was tested during the summer before the experiment took place, it is quite possible that it was not an accurate gauge of students' opinions.

Secondly, the Likert-scale format used, while convenient to set up and to score, presents a number of interpretation problems. For example, a middle-of-the-road score on a Likert test (i.e. a mean score of three) could be obtained by answering half the questions "Strongly Agree" and the other half "Strongly Disagree", but it could equally well be obtained by answering "Neutral" to them all. Thus, the same score cannot differentiate between two very different types of attitude. Other types of attitude-scale do exist (e.g. Thurstone's interval model) but they too are open to similar problems. Existing questionnaire models must be improved, or new models developed, before any accurate measuring of students' real attitudes can take place.

Thirdly, students do not like questionnaires. There is a built-in resistance to any kind of formalized data-gathering, and a tendency not to answer the questions seriously. In addition, in studies such as the present one where attitude shift must be measured by repeated administrations of the same questionnaire, student resistance increases even more. Many students in this project simply refused to fill out the same questionnaire more than once (as can be seen by the drop in sample size between Stage I and Stage II) and regarded the entire exercise as a stupid waste of time. More sophisticated testing models need to be developed that are not so obvious in their intent, especially for use with university-level students. In addition, better methods of measuring attitude shift are needed, to avoid annoying repetition.

The researcher still believes that differing modes of instruction do affect students' opinions of the course as a whole. The fact that students indicated a positive attitude towards the audio-visual component of the course, even while expressing a lack of enthusiasm for the course as a whole, might be an indication of this. Admittedly, the audio-visual opinion questionnaire was a better testing instrument, since it had been drawn from a larger question pool and tested on a larger sample. In addition, its statements were more concrete and straightforward (i.e. easier to agree or disagree with), and the questionnaire was only given once. Measurement of any kind of affective change is difficult, but would be less so if the testing instruments presently available were more sophisticated, more subtle, and more generally applicable to differing educational situations.

Additional research might also be carried out at Queen's to try and determine why all students, right across the class, liked geology less and less, the more of it they saw. Again, the drop in attitude might be due to flaws in the testing instrument. However, it might also indicate a need for major improvements in the course to make sure that course objectives are, in fact, being met. Still another possibilty, however, is that falling attitudes are a natural phenomenon at university level. A comparison of student attitudes in other first year courses might indicate whether geology was any more disappointing to students than any of their other subjects.

As far as the Geology Department is concerned, further development of the audio-visual lab material could be carried out following the same format as the four units prepared for this project. There is probably no need for further statistical evaluation, although informal evaluation of any additional lab material should be carried out, to ensure that the audio-visual lab is meeting its objectives.

In conclusion, then, this report has presented an account of a research project developed at Queen's Univeristy, to evaluate the differing effects of individualized audio-visual geology lab instruction, and regular geology lab instruction. Neither type of lab instruction was found to affect students' attitudes towards geology, or the marks they expected to receive in the course. Nor was type of lab instruction found to be related to students' test marks during the two-week controlled experimental period. However, when the entire Geology 010 class was taken into consideration over the first term period, it was found that in four of the eight class sections, students who had used the audio-visual lab material in addition to attending regular lab classes scored significantly higher on their lab tests ($p= <.05$) than those students who had attended regular lab classes only. Moreover, students made extensive use of the supplementary audio-visual lab material, and stated that they found it a very valuable source of review. It therefore seems logical that the audio-visual lab continue in a supplementary role to the regular lab instruction, but be expanded in order to accommodate more students and more lab material. In addition, further research needs to be carried out to improve testing procedures for students' attitudes towards course material.

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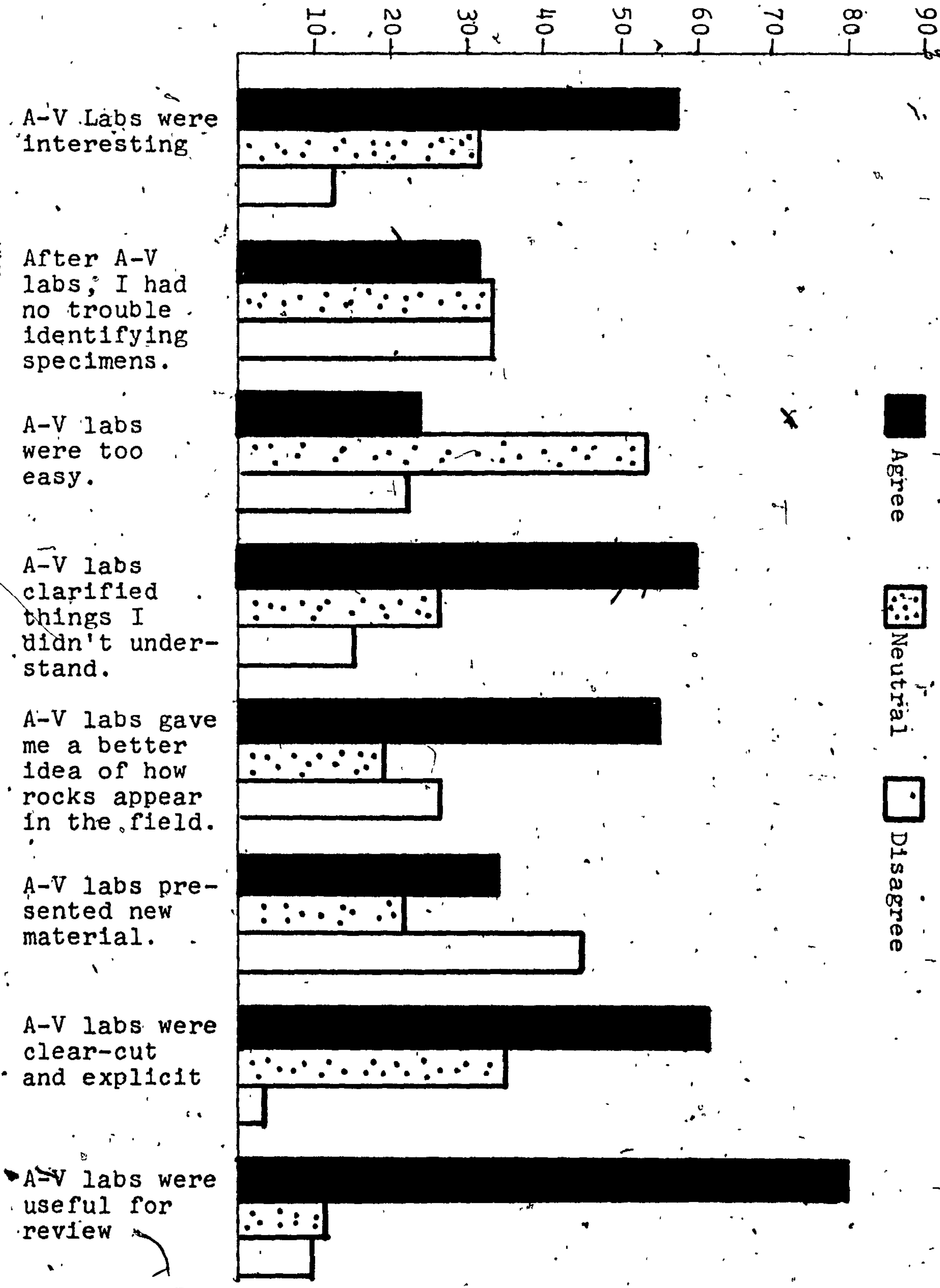
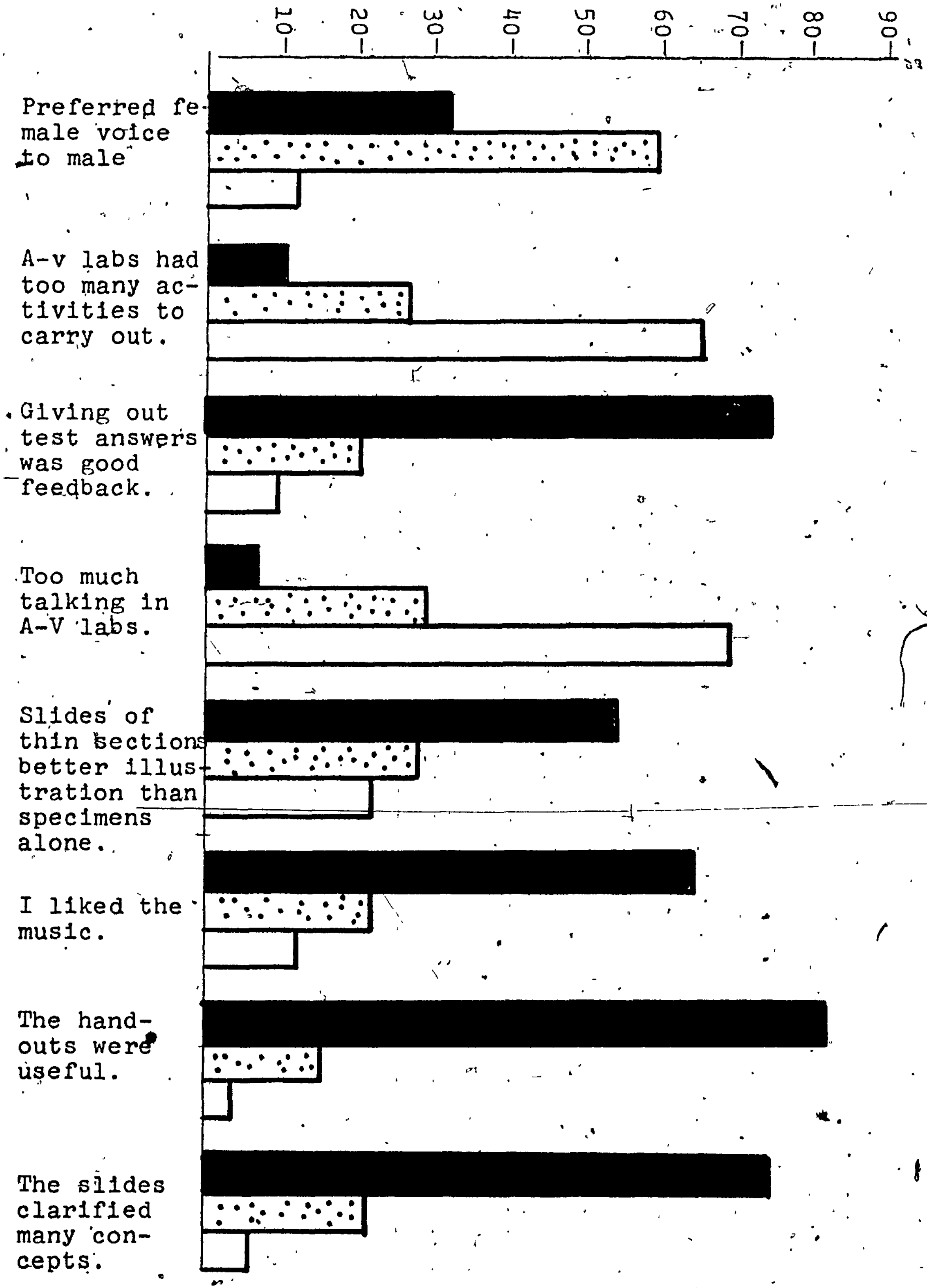
APPENDIX A

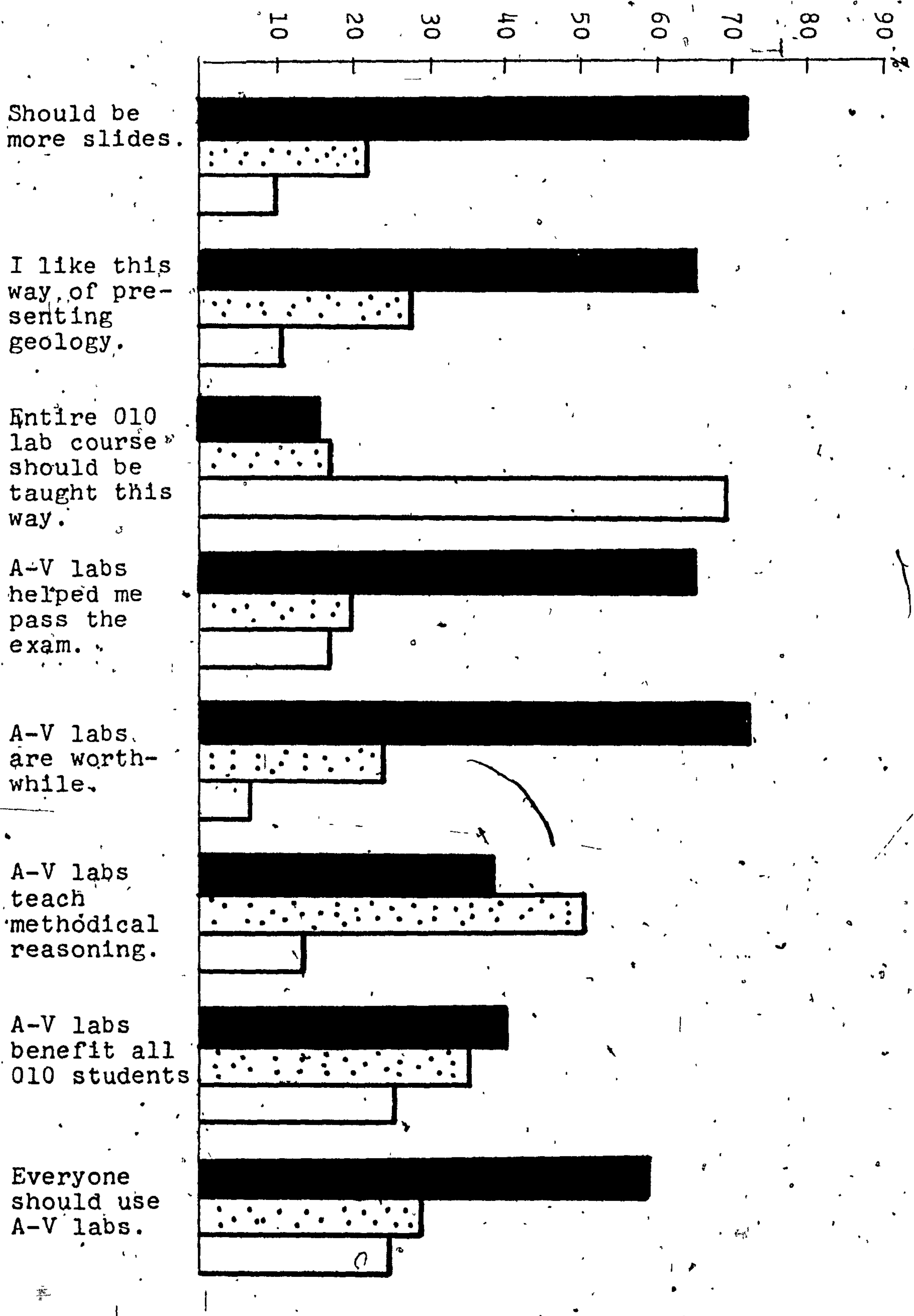
Audio-Visual Lab Questionnaire Results

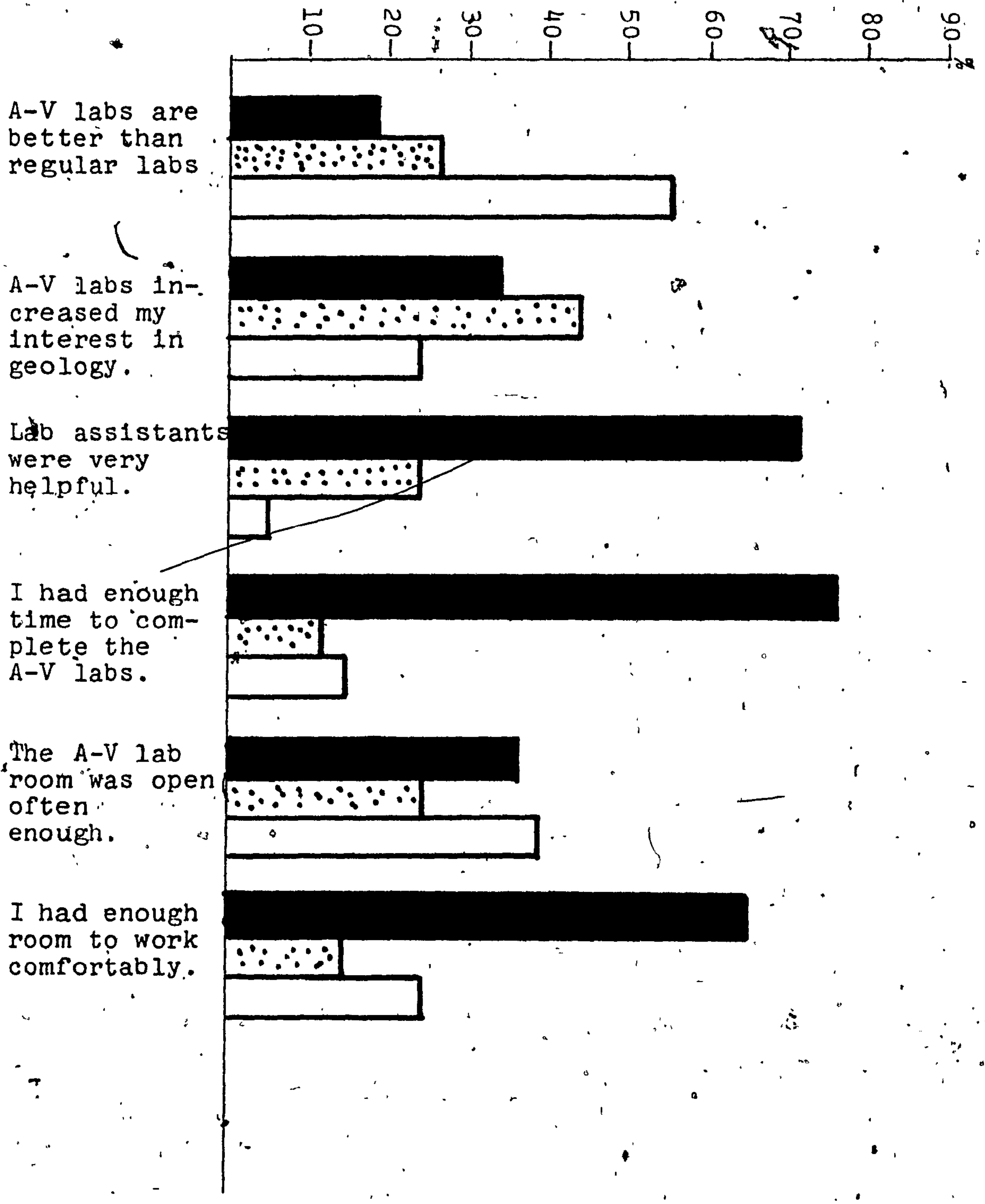
Pilot Study

Note:- The graphs indicate the responses to the positive phrasing of each question.


10
20
30
40
50
60
70
80
90
A-V Labs were interesting
After A-V labs, I had no trouble identifying specimens.
A-V labs were too easy.
A-V labs clarified things I didn't understand.
A-V labs gave me a better idea of how rocks appear in the field.
A-V labs presented new material.
A-V labs were clear-cut and explicit
A-V labs were useful for review
Agree
Neutral
Disagree


10
20
30
40
50
60
70
80
90
Preferred female voice to male
A-v labs had too many activities to carry out.
Giving out test answers was good feedback.
Too much talking in A-V labs.
Slides of thin sections better illustration than specimens alone.
I liked the music.
The handouts were useful.
The slides clarified many concepts.


10
20
30
40
50
60
70
80
90
%
Should be more slides.
I like this way of presenting geology.
Entire 010 lab course should be taught this way.
A-V labs helped me pass the exam.
A-V labs are worthwhile.
A-V labs teach methodical reasoning.
A-V labs benefit all 010 students
Everyone should use A-V labs.


10
20
30
40
50
60
70
80
90
A-V labs are better than regular labs
A-V labs increased my interest in geology.
Lab assistants were very helpful.
I had enough time to complete the A-V labs.
The A-V lab room was open often enough.
I had enough room to work comfortably.

APPENDIX B

Some Student Comments on the Audio-Visual Lab: Pilot Study

- I enjoyed them. They are helpful -- good as a supplement to regular classes.
- Excellent -- I couldn't quite reason out the identification process, and the lab helped greatly.
- Jokes poor.
- Good review -- shows things I was ignorant of. More pictures of rocks and minerals in different forms would help.
- Were good, but could use more depth.
- Very good for someone who needs clarification, but of little real interest to the more knowledgeable student.
- Extremely useful -- couldn't possibly have passed without them.
- A worthwhile supplement to the course, but not applicable as the only means of study.
- Cramped area needs spreading out.
- Get rid of the music.
- (Geological) Structures should be added.

APPENDIX C

Audio Tape Script and Lab Notes

Unit 1: Mineral Identification

VIDEO | AUDIO

Geology 010. Unit One. Minerals. (Music. "Diamonds are a girl's best friend).

I hope you realized the geological significance of that song. Unfortunately, you won't be studying diamonds on this course, as it turns out. But then, nobody seems to write songs about calcite or olivine either, so we'll just have to make do.

This unit on minerals is the first of four lab units dealing with rock and mineral identification. You'll be covering much of the theoretical background to rocks and minerals in your lecture periods, but in these four lab units, we want you to look closely at the rocks and minerals themselves.

In this first unit, our objective is to teach you how to identify some of the common minerals. Since rocks are made up of combinations of these minerals, it is most important that you know what you're doing at the end of this first unit. By then, you should be able to identify 15 common rock-forming minerals, and 8 ore-bearing minerals of the base metals iron, copper, zinc and lead.

In order to work through this lab unit, you'll need the lab notes for the audio-visual lab section, your textbook Rocks and minerals of Ontario, a penknife, a streak plate, a hand lens, a glass plate, and, of course, the tray of mineral specimens, numbers 1 to 23. If you don't have all of this equipment, turn off the tape and collect it now before you go any further.

At several points throughout this lab unit, you'll be asked to do various short identification exercises. You should turn off the tape recorder while doing these exercises, and you can check your answers with the list on the last page of your lab notes.

Are you ready then? We'll start off this unit with a brief definition of a mineral. A mineral is a naturally occurring, homogenous solid, inorganically formed, with a definite chemical composition, and an ordered atomic arrangement. Let's simplify that a bit. What this means is that organic substances, like coal or oil, cannot be classed as minerals even though they are recovered from the ground. Why not? Because they are organic. Synthetic minerals that can be made up, like imitation rubies, are not minerals either because they don't occur naturally.

The chemical composition of a mineral is definite, but not fixed. Some of the sulfide minerals can vary in the amount of sulfur they contain, for instance, but these variations are within a definite restricted range, and hence, still within the definition of a mineral.

There are some 2,000 different minerals in all, but don't panic! For this course, you will only have to know those 15 which commonly go to make up rocks, and 8 ore-bearing minerals which are mined for recovery of the metals they contain.

How can you identify these minerals? Well, the procedure is very straightforward. There are 7 physical properties of minerals that you can use to identify an unknown specimen. It's a bit like playing Sherlock Holmes. Each physical property will give you a clue to the specimen's identity, and when you've assembled all the clues, you can then deduce the name of the mineral you are examining.

I'll go through these physical properties one by one, and show you what kind of clues each one can give you. You'll find all these properties listed in your lab notes, so you can follow along if you like.

Let's start with colour. Now, very few minerals have just one distinctive colour, which isn't too helpful. However, there are a couple which can be identified that way. For example, olivine, which is #11 in your sample tray, almost always has this characteristic olive green colour. Pyrrhotite, the bronze-coloured mineral, #19 in your tray, and kyanite, the blue-coloured mineral, #13, are two more examples of minerals with a characteristic colour. But not all minerals are this cooperative.

Turn on the slide projector and look at the first slide.

Slide 1:
3 colours
of quartz.

This slide shows you 3 specimens of the same mineral: quartz. You'll notice that they have 3 very distinct colours. The rose quartz is a sort of pinky colour. The smoky quartz is the greyish specimen. And milky quartz, the most common form of quartz, is this whitish or translucent colour.

Look at sample #8 on your tray. What colour of quartz is this? Turn off the tape while you decide, then check your answer on the last page of the lab notes → the first answer.

The right answer, of course, was milky quartz.

Now look at slide number 2.

Slide 2:
2 colours of
plagioclase

Here you see two specimens of a plagioclase, which is one of the feldspars. The reason for the colour difference there is a slight difference in the chemical make-up of the two samples.

Change the slide, please.

Slide 3:
2 colours of
sphalerite

Here are another two specimens that look completely different, but are, in fact, both pieces of sphalerite. The light brown coloured one contains only zinc and sulfur, while the very dark brown specimen has iron replacing some of the zinc atoms.

Next slide, please.

Slide 4:
2 colours of
pyroxene

Here is a final example of the way in which mineral samples can set out to confuse you. Both of these very different-coloured specimens are pyroxene, and as with sphalerite, the colour variations are due to variations in atomic composition. Which only goes to prove that you can't always judge a mineral by its colour.

So with that, we'll move on to some of the other identifying features of minerals.

You can turn off the slide projector for the moment.

The second of the physical properties of a mineral is cleavage. And, by the way, this has nothing to do with necklines. It refers to the way the mineral will split along planes. Turn off the tape recorder for a moment, and read what your lab notes say about cleavage on page 2.

Turn on the slide projector again, please. The next 3 slides will show you examples of different types of cleavage. Take a look at the first of these slides now.

Slide 5: 1-directional cleavage.

In this slide, you can see what cleavage along one plane looks like. Take sample #3 on your tray, and look for the one cleavage plane. Then change the slide.

Slide 6: 2-directional cleavage.

Here is cleavage in two directions. Take samples #6 and #9 from your tray, and try to locate the two cleavage planes that they should show. The smooth straight surfaces are the cleavage faces. Turn off the tape recorder if you want more time.

Next slide, please.

Slide 7: 3-directional cleavage.

Finally, cleavage along three planes. You don't have halite in your tray, but look at sample #16 for cubic cleavage. Calcite is #2 in the set, and you should be able to see the rhombohedral cleavage that the slide illustrates.

Go on to the next slide when you're ready.

Slide 8:
Galena:
cubic cleavage

Here we have a close-up look at the cubic cleavage in galena. The specimen shown here has the characteristic steely blue colour, and the cleavage angles of 90°. Specimens of galena will often break up into nearly perfect cubes.

Look once again at your specimen of galena, #16. Can you see the way it breaks along cubic faces? You may not find perfect cubes in your specimen, but you should be able to see at least three faces, all at right angles to each other.

Now look at the next slide.

Slide 9
Pyroxene &
amphibole
cleavage angles

This shows samples of pyroxene and amphibole which can be distinguished from each other by the angle of their cleavage planes. Pyroxene has an angle of about 90° as you can see here, whereas amphibole cleaves at an angle of approximately 60° or 120°. Since both pyroxene and amphibole can often be very nearly black, the only way you can tell which is which in a hand specimen is to compare the different cleavage angles.

Look at specimens #10 and #9. Examine the cleavage angles and decide which one is pyroxene and which is amphibole. Check with answer #2 on the sheet when you think you know.

Next slide, please.

Slide 10: quartz, calcite & galena. Cleavage and fracture.

Now, to sum up what you've learned so far about cleavage, here is a slide showing samples of quartz, calcite, and galena. Quartz, you'll see, has no cleavage -- everything just breaks along jagged irregular faces. Calcite, on the other hand, has very good cleavage along three different faces to give rhombohedral cleavage. And I've already talked about galena, which has three-directional cubic cleavage.

We'll leave cleavage now and talk about the third identifying characteristic of a mineral -- fracture. You can turn off the slide projector for awhile.

Fracture refers to the way a mineral breaks along irregular surfaces. Cleavage, you will recall, occurs along flat surfaces or planes. We'll now examine 3 types of fracture -- conchoidal, uneven, and splintery fracture.

Pick up specimen #8 from your tray, and examine it with the hand lens. Are there any cleavage faces? What does the surface of this specimen look like? Check with answer #3 when you have decided.

The fractures with curved surfaces that you saw that may have looked like pieces of broken beer bottle, are called conchoidal fractures -- curved like the surface of a shell.

Now pick up specimen #23 and decide whether it has any cleavage planes, or any kind of fracture pattern. Check your answers with #4 on the answer sheet before continuing.

You should have found that #23 had no cleavage planes -- no straight, smooth surfaces. Nor does it fracture in a particular way, as does specimen #8, but breaks up in what we call uneven fracture.

The third type of fracture, splintery fracture, can be seen in specimen #5, and the name "splintery" pretty well describes itself.

Just to make sure that you understand the difference between cleavage and fracture, look at specimen #7 and specimen #21. Which one shows cleavage and which one shows fracture? How many cleavage planes does the cleavage specimen have? What kind of fracture does the fracture specimen show? Check your findings with the answer sheet before continuing.

We'll move on now to a[illegible] important diagnostic feature, st[illegible] and you'll all be relieved to know that I'm going to restrain myself from making a corny joke about streakers.

Streak is an especially useful test for the metallic sulphide minerals, and some of the metallic oxides too. Streak refers to the colour of the mineral powder, and you can find this out by scratching the mineral on that unglazed porcelain plate that you should have with you.

Try a streak test now on specimen #17. When you scratch the mineral on the plate, what colour of powder do you find?

Check with the answer sheet.

Sometimes, minerals which look very much alike can be distinguished by the colour of their respective streaks. Take the two minerals #20 and #21 in your tray. Both of these minerals are iron ores, and they often have almost the same colour, and you might have trouble telling them apart. But let's have a look at their streaks.

Scratch each specimen on the porcelain plate and note the colour of the streak. What do you find? Check your conclusion with the answer sheet.

With the streak test, you have learned another way of distinguishing similar looking minerals from each other.

The fifth physical feature we'll look at is lustre. The lustre of a mineral is the way that ordinary light is reflected off its surface. Metallic lustre, for example is like that of a polished metal, and most of the metal sulphide minerals have this feature. Look at specimen #16 for example. There are various other kinds of lustre: adamantine -

like a diamond; vitreous - like glass; pearly, silky, resinous, and dull - when no light is reflected at all. Your specimen #5 has a resinous lustre, and #8 has a vitreous lustre.

Now you try a few. Take the 3 samples #23, #7 and #9. Look at them carefully (you may need the hand lens) and decide what lustre each has: metallic, vitreous, pearly, resinous, adamantine, silky, or dull. Some of the specimens may show more than one lustre, so take this into consideration. Check your findings with answer #8 on the sheet before you continue.

We'll move on to hardness, which is another very important diagnostic feature. In fact, this is the first test you should make when identifying an unknown specimen. The hardness is easy to determine, and once you've done this, you can eliminate a large number of possibilities in your search for the identify of the mineral.

To classify the hardness of a mineral, first look at Moh's Scale of Hardness on page 2 of your lab notes for this unit. There you'll find a list of 10 minerals on a scale of 1 to 10 -- 10 being the hardest. You'll also find the hardness of glass, a knife blade, etc. listed. To test for hardness, all you do is try to scratch some of these materials with the mineral specimen. Try to scratch the glass plate first. If you can make a scratch on the plate, then the mineral is harder than glass -- somewhere in the 5.0 to 5.5 range. Then try to scratch the mineral with your penknife. If you can't make a scratch with the knife blade, then the mineral is harder than the knife -- somewhere in the 5.5 to 6.0 range of hardness. You can also try to scratch one mineral with another to see which is harder.

By the way, the difference between a scratch and a streak is that a scratch leaves a mark on the mineral, but a streak mark will rub off.

Let's try a hardness test. Take specimen #17 and try to make it scratch a glass plate. If it will scratch the glass plate, then try to scratch the specimen with your knife. Don't gouge the thing all to bits -- just a fine scratch with the point of your knife. If the specimen won't scratch the glass, though, then try to make it scratch a copper coin. When you've carried out these tests, look at the Scale of Hardness in your lab notes, and decide what the hardness of this specimen is. Compare your findings with answer #9 on the sheet before going any further.

You should have found that the sample is softer than glass but harder than the copper coin. So that puts the hardness in the 3.5 to 5.0 range. You should also have noticed, if you scratched the specimen with your knife, that you got a brown powder. So you've really done two tests in one -- the hardness and the streak test.

Try one more hardness test. Take specimen #8 and try to determine its hardness. Again, check your answer before continuing.

Next, we'll briefly look at specific

gravity, which is the seventh diagnostic feature of a mineral.

In essence, the specific gravity is really just the weight of the mineral relative to another mineral sample of the same size. Compare the weight of sample #16 with any one of the samples #1 to #15 making sure that the sample you choose is about the same size as your sample #16. What do you find? Check with answer #11 on the sheet.

"Heavy as lead" is a very apt description for #16, because it's a lead sulphide.

At this stage, you won't have to learn how to determine the exact specific gravity of a mineral. It's enough just to know that some minerals are heavier than others, and the only way to find out is to heft the samples and see which weighs more.

You've now learned the 7 physical features of a mineral that can be used to identify unknown specimens. But there are two more characteristics of a mineral that I want to mention briefly: crystal form and chemical composition.

Each mineral has a characteristic crystal form -- a characteristic geometric shape in which it grows. None of the specimens in your tray show good crystal form, however, and this was done on purpose, since it's not very often that you'll find well-formed crystals in rocks. This is because the conditions under which rocks are formed are not conditions that will allow perfect crystal forms to grow. But it's interesting to see what perfect crystals do look like, so turn on your slide projector, and look at slide #11.

Slide 11:
Amethyst crystals

This shows crystals of amethyst, with its beautiful purple colour. If you're very lucky, you can sometimes find amethyst crystals along the gravel beaches of the north shore of Lake Superior.

Now change the slide, please.

Slide 12:
Wulfenite crystals

This shows a crystal of wulfenite - a mineral containing lead and molybdenum. You'll see that it's almost unreal in the evenness of the angles and the way the sides have been formed.

Next slide please.

Slide 13:
Wulfenite crystals

Here is the same mineral again, and it's growing in a finer, black mineral. Again, you can see the beautiful, translucent crystals with 90° corners on them. Crystals like these are collector's items, and you'll find some very good examples in the display cases here in Miller Hall.

Now look at the next slide.

Slide 14:
Quartz crystals

In this slide, the clear crystals are quartz, and the rose-coloured crystals are rhodochrosite -- a manganese bearing mineral.

Change the slide, please.

Slide 15:
Orthoclase crystal
& fragment

Now I want you to think back to what you learned about cleavage for a moment, because I want to make clear the difference between a cleavage fragment and a crystal. In this slide, you see two samples of the same mineral -- orthoclase. On the left are orthoclase crystals, and on the right, a cleavage fragment of orthoclase. Look at sample #16 in your tray and compare it with the cleavage fragment shown in the slide. Orthoclase has such good cleavage on three planes, that it breaks into pieces that you might mistake for crystals. Your specimen should show at least two of these cleavage faces, but these are produced by splitting along the cleavage planes -- they haven't grown that way, as crystals do.

Turn off the slide projector now, and we'll look briefly at the chemical composition of the minerals on your tray.

At this stage in your geology course, we would expect you to know the composition of the minerals, but we're not going to have you memorize all the exact formulae. On the mineral chart at the back of your lab notes, you'll find listed the chmical composition, and formulae for each mineral in your tray. Have a look at this chart now.

If you haven't taken any chemistry in high school, you may wonder what silicates, carbonates, oxides and sulphides are. A silicate is a mineral with silicon and oxygen as part of its chemical composition. Olivine, biotite, amphibole, quartz, orthoclase, pyroxene, and plagioclase are all silicate minerals. Carbonates, such as calcite, have carbon and oxygen in their chemical make-up. Oxides have oxygen, plus one or two other elements. Quartz, for example, is a silicon oxide and magnetite is an iron oxide. Sulphides are minerals with sulphur plus one or two metallic elements. Your specimens numbers 16, 17, 18 and 23 are all sulphides. #16 is a lead sulphide, #17 a zinc sulphide, #18 a copper-iron sulphide, and #23 is an iron sulphide.

I should also point out at this stage that the specimens on your tray are, in most cases, composed only of the one mineral they are meant to illustrate. However, minerals don't usually occur like this -- in large, homogenous chunks. In a rock, you'll generally find a variety of different minerals dispersed throughout the rock mass, and some of the mineral crystals will be very minute. The specimens on your tray, then, are a little bit unusual in that they have come from places where there was a high concentration of the mineral -- for example, from a vein or a vug. On the field trip that you'll be taking later this term, you'll see some examples of these concentrations of minerals within their surrounding rock mass.

Having said all this, we can now move on to the important part of this lab unit -- showing you how to identify mineral samples, according to the diagnostic features already discussed. I'll identify one sample with you, then you'll do the rest yourself.

You'll need the worksheet for mineral identification at the back of your lab notes, your knife, glass plate, streak plate, hand lens, and the mineral identification chart at the front of your lab notes -- the one without the specimen numbers on it! Have you got everything?

Now, I'll identify sample #7 according to the proper procedure, as outlined on the worksheet. For each step of the identification, I'll tell you how to carry out the various tests, but I want you to figure out the answers yourself. You should stop the tape each time you're asked to carry out a test, and check your findings with the answer sheet before turning on the tape again.

All right, pick up sample #7 and we'll start the identification procedure.

Always do the hardness test first, since this will quickly narrow your list of possibilities. Try scratching the specimen on the glass plate, then try scratching it with the knife, or with a copper coin or fingernail if it's softer than glass. Referring to the Scale of Hardness in your lab notes, decide what is the hardness of this specimen, and enter this figure on the worksheet.

Now, what colour is this specimen? Write down your answer on the worksheet.

Next, do the streak test. Make a streak on the porcelain plate with the specimen, and note the colour of the streak on the worksheet.

The next heading on the worksheet is crystal habit, but since we've talked very little about this, and since none of the samples in your tray show crystal form, just bypass this column entirely.

What about the cleavage? Can you see any cleavage faces on the specimen? If so, how many and what are their angles? If there is no cleavage, what kind of fracture does the specimen have? Write all this down on the worksheet.

Now, the lustre. What do you think is the lustre of this specimen? Look back at your lab notes if you've forgotten the different types of lustre, then write down your choice on the worksheet.

The specific gravity comes next. Does the specimen feel heavy? Would you say that it has a high or a low specific gravity?

Now that you've filled in the information on the worksheet, and assembled all the clues, you can turn to the mineral identification chart at the front of your lab notes. To decide which mineral you are investigating, first of all eliminate all those minerals with hardness less than 6.0. Then look at the descriptions of those minerals that are left to see which fits the identifying description that you've made up. So, let's start down the list.

It isn't amphibole, because amphibole has the wrong colour, and the wrong streak. Pyroxene, uraninite, and hematite are out for the same reason. Kyanite might have the same colour, but it has a colourless streak. Chromite and magnetite have no cleavage, and are also the wrong colour and streak.

The next mineral on the list is orthoclase and this begins to sound a little more like our specimen. It has one perfect and one good cleavage at an angle of 90°, which is what you should see in this specimen. The colour, lustre, and streak are right, but before you decide that you've found the answer, look at the next name on the list -- plagioclase. The descriptions of these two minerals are nearly identical, you'll note, except for the fact that plagioclase usually shows striations. Striations are closely-spaced parallel lines that can be seen by turning the cleavage faces to the light. Look closely at your specimen. You should, in fact, be able to see the striations on the cleavage faces. This means that the specimen is plagioclase.

Double check your conclusion by running through the rest of the list.

Now it's your turn to identify the rest of the specimens in your tray. Some of them you will be able to recognize immediately, but nevertheless, go through the complete identification procedure for each one, and check your answers with the mineral chart at the back of your lab notes. In several cases, you'll find two specimens with the same number in your tray. These double specimens are included to show the differences which can occur in some minerals. You should try the identification procedure on both examples, and make sure that you get the same answer.

If you have any questions about the identification procedure or if you have difficulties of any kind, ask the lab demonstrator for help, or refer to your textbook or lab notes. When you have finished the identification exercise, you will have completed the lab unit on mineral identification.

Before you leave the lab, though, take a look at the displays of minerals set up in the lab room. You should also look at the samples of minerals in the display cases in Miller Hall, both on this floor and on the third floor. They will provide more exotic examples of minerals than we were able to put on your sample tray.

(Music. "Diamonds are a girl's best friend".)

PHYSICAL PROPERTIES OF SOME IMPORTANT MINERALS

Hardness	Colour and Streak	Cleavage or Fracture	Other Properties	Mineral Name	Combosition
1	C-White to green S-White	One perfect cleavage yielding thin scales	Greasy or soapy feel pearly luster	TALC	$Mg_6(Si_8O_{20})(OH)_4$
1	C-Black to gray S-Black	One perfect cleavage	Greasy feel; luster metallic to dull; writes	GRAPHITE	Carbon
1-2	C-White S-White	Perfect cleavage, but invisible to naked eye	Luster dull or nearly; greasy feel; adheres to tongue; writes	KAOLINITE ("tailor's chalk")	$Al_2Si_2O_5(OH)_4$
1-2.5	C-Green S-Greenish	One perfect cleavage yielding thin scales	Translucent to opaque; vitreous luster	CHLORITE	Hydrous Al-silicate of Mg, Fe
1-5.5	C-Yellow to brown S-Yellowish brown	No cleavage; may have conchoidal fracture	opaque; dull luster	LIMONITE	$Fe_2O_3 \cdot nH_2O$
2	C-White, gray, pink S-White	One perfect cleavage yielding thin foils; less perfect in two other directions	Transparent to opaque; luster silky, pearly, or dull	GYPSUM	$CaSO_4 \cdot 2H_2O$
2-2.5	C-Colorless, white, gray S-White	Three perfect cleavages at right angles	Transparent to translucent: salt taste	HALITE ("rock salt")	NaCl
2-2.5	C-Scarlet to brownish red and lead-gray S-Scarlet	Perfect cleavage.	Opaque to translucent (in thin pieces); dull or adamantine to slightly metallic luster; very heavy.	CINNABAR (mercury ore)	HgS

Hardness	Colour and Streak	Cleavage or Fracture	Other Properties	Mineral Name	Composition
2-3	C-Colorless to light brown S-White	One perfect cleavage yielding thin scales	Transparent to translucent; luster pearly to vitreous	MUSCOVITE ("light mica")	Hydrous Al-silicate of K
2-6 (massive) 6-6.5 (crystals)	C-Dark bluish gray to black S-bluish black	One perfect cleavage; uneven fracture	Opaque; metallic luster to dull; heavy	PYROLUSITE (manganese ore)	MnO_2
2.5-3	C-Black to dark brown S-White to greenish	One perfect cleavage yielding thin scales	Translucent to opaque; luster pearly to vitreous	BIOTITE ("dark mica")	Hydrous Al-silicate of K, Mg, Fe
2.5-3	C-Lead gray S-Gray, to black	Three perfect cleavages at right angles	Metallic luster; heavy	GALENA (lead ore)	PbS
2.5-4	C-light or dark green S-White to greenish	Cleavage invisible to naked eye; splintery fracture; curved slip planes	Translucent to opaque; luster dull to greasy, rough or greasy feel	SERPENTINE	$Mg_3Si_2O_5(OH)_4$
3	C-Colourless to variously tinted S-White	Three highly perfect cleavages not at right angles	Often transparent; vitreous luster; double refraction; effervesces in HCl	CALCITE	$CaCO_3$
3	C-Reddish gray with purplish-blue iridescence S-Gray to black	Indistinct cleavage; conchoidal fracture	Opaque; metallic luster; heavy	BORNITE (copper ore)	Cu_5FeS_4
3.5	C-Bronze S-grey-black	no cleavage	metallic lustre; slightly magnetic	PYRRHOTITE	$Fe_{1-x}S$

Hardness	Colour and Streak	Cleavage or Fracture	Other Properties	Mineral Name	Composition
3.5-4	C-White to variously tinted S-White	Three perfect cleavages not at right angles	Transparent to translucent; vitreous luster; powder effervesces slowly in HCl	DOLOMITE.	$CaMg(CO_3)_2$
3.5-4	C-Bronze-yellow S-Bronze-brown to black	Distinct parting in rare crystals; conchoidal fracture	Opaque; metallic luster; heavy	PENTLANDITE (nickel ore)	$(Fe,Ni)_9S_8$
3.5-4	C-Yellowish brown to black S-Brownish yellow	Highly perfect in six planes at 60° angles	Translucent to opaque; luster resinous to adamatine	SPHALERITE (zinc ore)	ZnS
3.5-4	C-Golden yellow S-Greenish black	No cleavage; uneven fracture	Opaque; metallic luster, iridescent tarnish	CHALCOPYRITE (copper ore)	$CuFeS_2$
3.5-4	C-Emerald green S-Lighter green	One good cleavage in rare crystals; uneven fracture	Opaque to slightly translucent; luster vitreous or silky to dull	MALACHITE (copper ore)	$CuCO_3 \cdot Cu(OH)_2$
5-6	C-Green to black S-Greenish gray	Two good cleavages at 56° angles	Opaque; vitreous luster	AMPHIBOLE (var. hornblende)	Hydrous al-silicates of Ca, Mg
5-6	C-Greenish black S-Greenish gray	Two fair cleavages at almost right angles	Opaque; luster vitreous to dull	PYROXENE (var. augite)	Silicate of Ca, Mg (Fe,Al)
5-6	C-Pitch-black or grayish, greenish or brownish black S-Green or dark to brownish gray	Uneven to conchoidal fracture	Opaque to translucent (in thin pieces) luster submetallic to greasy, pitch-like, or dull; very heavy	URANINITE (uranium ore)	UO_2

Hardness	Color and Streak	Cleavage or Fracture	Other Properties	Mineral Name	Composition
5-6.5	C-Red, gray, or black S-Red	No cleavage through individual crystals, but parting between crystals in flaky aggregates.	Opaque; luster metallic or dull; earthy aggregates may be soft.	HEMATITE (iron ore)	Fe_2O_3
5-7.5	C-Blue-white to black S-Colorless	One perfect cleavage; one good cleavage	Vitreous luster	KYANITE	Al_2SiO_3
5.5	C-Black to brownish black S-Brown	No cleavage; uneven fracture	Opaque; metallic luster; heavy. Resembles magnetite, but feebly or nonmagnetic	CHROMITE (chromium ore)	$FeCr_2O_4$
5.5-6.5	C-Black S-Black	No cleavage; uneven or conchoidal fracture or rough parting	Opaque; metallic luster; heavy; magnetic,	MAGNETITE (iron ore)	$FeO \cdot Fe_2O_3$
6	C-White or pink S-White	One good and one perfect cleavage approximately 90° angles.	Translucent to opaque; vitreous luster	ORTHOCLASE FELDSPAR	$KAlSi_3O_8$
6-6.5	C-Grayish, bluish, whitish S-White	Two cleavages at 86° angles, one very good	Translucent to opaque; vitreous luster may have color play: striations	PLAGIOCLASE FELDSPAR (var. labradorite)	$NaAlSi_3O_8$ and $CaAl_2Si_2O_8$ in varying proportions
6-6.5	C-Brass yellow S-Greenish black	No cleavage; uneven fracture	Opaque; metallic luster; striated faces	PYRITE. ("fools gold")	FeS_2
6-7	C-Brown to black S-White to pale yellow	No cleavage; fracture uneven or conchoidal	Translucent to opaque; luster highly vitreous ("adamantine"); heavy	CASSITERITE (tin ore)	SnO_2

Hardness	Color and Streak	Cleavage or Fracture	Other Properties	Mineral Name	Composition
6-7	C-Pistachio green S-Colorless to gray	One perfect cleavage; a second poorer cleavage at 115°	Vitreous luster	EPIDOTE	Hydrous silicate of: Ca, Al, Fe
6.5-7	C-Green S-White	Very poor cleavage; conchoidal fracture	Transparent to translucent; vitreous luster	OLIVINE	$(Fe,Mg)_2SiO_4$
6.5-7.5	C-Variously tinted, usually red S-White	No cleavage; uneven or conchoidal fracture	Translucent to opaque; luster resinous to vitreous	GARNET	Silicates mainly of Ca, Fe, Al
7	C-Colorless, white or tinted by impurities S-White	No cleavage; uneven or conchoidal fracture	Transparent, translucent or opaque; vitreous luster	QUARTZ ("rock crystal") (var. milky, rose)	SiO_2
7 or slightly less	C-White or tinted by impurities S-White	No cleavage; conchoidal fracture	Transparent to opaque; luster vitreous to dull	CHALCEDONY (var. flint, chert, agate)	SiO_2
7-7.5	C-Reddish brown to black S-Colorless to gray	Fair cleavage in one direction	Nearly opaque	STAUROLITE	Silicate of Fe, Al
7.5	C-White, grey, rose-red, brown S-White	one distinct cleavage	vitreous to dull lustre; coarse prismatic crystals with nearly square cross-section	ANDALUSITE	Al_2SiO_5

SESSION NO. 1 -- IDENTIFICATION OF MINERALS

OBJECTIVE - To learn to identify the minerals commonly found in rocks, so that the different types of rock may be recognized; and to identify some of the ore minerals of iron, copper, zinc and lead.

DEFINITION - A mineral is a naturally occurring homogeneous solid, inorganically formed, with a definite chemical composition and an ordered atomic arrangement (Berry & Mason).

The requirement that a mineral be naturally occurring eliminates the synthetic rubies and spinels and other such crystalline compounds made by man.

Being a homogeneous solid the mineral cannot be separated into simpler compounds by physical means, and the requirement that it be solid eliminates gases and liquids -- thus, ice is a mineral but water and petroleum are not. Substances formed by or from plants and animals are not strictly minerals since they are of organic origin. This eliminates coal, peat, and sea shells.

The chemical composition is definite but not fixed; many minerals have varying proportions of major and minor elements but these variations lie within fixed limits.

The ordered atomic arrangement is characteristic of each mineral; it is sometimes responsible for development of diagnostic crystal forms.

Although over 2000 minerals have been recognized and described only about 20 are abundant constituents of the earth's crust. In addition, of the 92 naturally-occurring elements only nine, arranged in different combinations, make up most of the common minerals. These nine elements are: (chemical symbol in brackets) oxygen (O), silicon (Si), aluminum (Al), magnesium (Mg), calcium (Ca), sodium (Na), potassium (K), iron (Fe) and hydrogen (H).

PHYSICAL PROPERTIES OF MINERALS - The unique properties of each mineral are determined both by the chemical elements composing it and the manner in which these elements are arranged within the mineral structure. Positive identification of many minerals requires advanced laboratory equipment such as a microscope, or an X-ray unit, but the more common minerals to be studied in this preliminary course can often be identified by visual inspection (i.e., naked eye or 10X hand lens). The readily-determinable physical properties used in mineral identification are: hardness, cleavage, lustre, colour, streak, fracture, and specific gravity. Some of these properties are more important than others in the recognition of a particular mineral and are thus diagnostic properties. Thus, one mineral may be recognized by its specific gravity, another by its colour.

HARDNESS - This is a measure of the resistance to "permanent" abrasion or scratching (to distinguish between a scratch and a streak -- the streak rubs off). Hardness should be tested on a fresh surface, since weathering causes development of new minerals, usually with lower hardnesses than the original mineral.

A scale of hardness, developed by Mohs in 1822, lists ten minerals of differing hardness so arranged that each mineral scratches the one preceding it on the scale.

Moh's Scale of Hardness

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond (hardest)

N.B. This scale is not linear; diamond is many times harder than corundum.

For simple field tests the following hardnesses may be used:

Thumb nail - 2.5
Copper Coin - 3.5
Glass - 5.0 to 5.5
Knife blade - 5.5 to 6.0
File - 6.5 to 7.0

Since hardness is one of the most useful properties for mineral identification, it should be one of the first tests to be made.

CLEAVAGE - The tendency of a mineral to cleave or split along definite parallel planes, or along intersecting sets of planes, is due to the arrangement of atoms and inter-atomic bonds within the mineral. This property dominates the physical appearance of several minerals, particularly the micas, which possess one direction of perfect cleavage ("micaceous cleavage"), causing them to split readily into thin sheets.

In other minerals, cleavage is less strikingly shown, but may be of diagnostic value. Thus, the generally physically similar dark Fe-Mg silicate families, the pyroxenes (e.g., augite) and amphiboles (e.g., hornblende) each exhibit two directions of good cleavage, but in the former these intersect at right-angles (actually 86°), and in the latter at 60° (actually 56°).

LUSTRE - is the manner in which light is reflected from the surface of the mineral. A new copper coin or a polished steel bar is bright and shining, and it is said to have a metallic lustre. If exposed to the weather for a year, the copper coin will develop a dull green coating and the steel bar will become rusty. Both will now have a non-metallic lustre. Some types of non-metallic lustre and minerals exhibiting these lustres are:

Vitreous or glassy - quartz
Resinous - sphalerite
Greasy or waxy - serpentine
Pearly - mica
Dull or earthy - limonite

COLOUR - Although this is probably the first noticeable physical property of a mineral its use in identification is often unsatisfactory because many minerals have a wide range of colour (e.g., quartz which ranges from colourless through red, yellow, mauve, black to white). However some minerals usually have a distinctive colour (e.g., olivine, galena).

STREAK - The colour of the powdered mineral is more consistent than the colour of the unbroken mineral; for instance all the varieties of quartz mentioned above have a white streak. Look-alike metallic minerals, such as pyrite and chalcopyrite, can be distinguished by the colour of their streaks.

The streak is determined by rubbing a fresh surface of the mineral on a piece of unglazed porcelain (streak plate). If the streak appears to be black rub it with your finger to see if it is truly black.

A useful rule is that most dark, metallic, minerals yield a streak which is darker than the mineral specimen, while dark, non-metallic minerals have a streak which is lighter in colour than the specimen.

FRACTURE - The manner in which a mineral breaks: uneven - like a broken brick; splintery - like long-grained hardwood; conchoidal - with concave surfaces such as result when thick glass or thick clear ice is broken.

SPECIFIC GRAVITY - The weight relative to the weight of an equal volume of water: the specific gravity of most common non-metallic minerals lies between 2.5 and 3.0; but that of most metallic minerals is higher than 3.0.

IDENTIFICATION PROCEDURE -

Equipment required: pocket knife; hand lens (8X or 10X); glass plate; and streak plate.

Procedure: Fifteen non-metallic and eight metallic minerals are presented in this laboratory course. They are listed in order of hardness for each group, so that is the first feature you should test. Until you become familiar with the minerals it is best to follow an orderly series of tests as given on the sheets. With familiarity you will soon recognize certain minerals by their diagnostic properties (which are denoted by asterisks on the lists).

COMMON ROCK-FORMING AND ORE MINERALS

LUSTRE: Non-metallic
HARDNESS: 2 1/2 to 7 1/2

No	Name	Composition	H	Cleavage or fracture	Lustre	Colour	Streak	Miscellaneous	Uses
1	Chlorite	Hydrous Mg, Al, silicate containing Fe, & other elements in small amounts.	2 1/2	*1 perfect	pearly; often dull	*green to dark green	white to pale green	*cleavage flakes are flexible but not-elastic	------
2	Calcite	$CaCO_3$	3	*3 highly perfect cleavages at oblique angles	vitreous to dull	colourless, white, yellow, pink, blue	white	*effervesces with cold dilute HCl	mfg. of cement; building & ornamental material; flux; agriculture
3	Biotite	Hydrous K, Al, Mg, Fe silicate	2 1/2	*1 perfect	pearly or vitreous	dark green, brown or black	white	*flexible, elastic, cleavage flakes	variety phlogopite used as insulator
4	Muscovite	Hydrous K, Al, silicate	2 1/2	*1 perfect	vitreous or pearly	colourless or pale green, grey or brown	white	*flexible, elastic cleavage flakes	insulator, lubricant
5	Serpentine	Hydrous Mg silicate	4-6	none, splintery fracture	waxy	green, also yellow, brown, grey	white	massive, columnar, or fibrous	fibrous variety is principal source of asbestos (chrysotile)

No	Name	Composition	H	Cleavage or fracture	Lustre	Colour	Streak	Miscellaneous	Uses
6	Orthoclase	$KAlSi_3O_8$	6	*2 nearly at right angles	vitreous	pink to red, grey, white	white	distinguish from plagioclase by absence of striations	porcelain manufacture
7	Plagioclase	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$	6	*2 nearly at right angles	vitreous	white or grey sometimes reddish or reddish-brown	white	"polysynthetic" (Lamellar) *twinning striations on the better cleavage surfaces	manufacture of ceramics
8	Quartz	SiO_2	*7	none, conchoidal fracture	vitreous, sometimes greasy	colourless, milky, rose, black, mauve (amethyst)	white	sometimes in hexagonal-shaped crystals. var.; agate, jasper, chalcedony	abrasive; mfg. of glass; smelting flux; construction ornamental
9	Amphibole (Hornblende)	Hydrous Na, Ca, Fe, Mg, Al, silicate	6	*2 at 56° and 124°	vitreous to dull	black to greenish black	white to greenish grey	crystals elongate, commonly 6-sided prisms Also massive.	------
10	Pyroxene (Augite, Diopside)	$Ca(Mg,Fe)Si_2O_6$	6	*2 at 86° and 94°	vitreous to dull	dark green to black (Augite) white to pale green (Diopside)	white to grey	crystals 4 to 8 sided stubby prisms. Also massive.	------

No	Name	Composition	H	Cleavage or fracture	Lustre	Colour	Streak	Miscellaneous	Uses
11	Olivine	$(Mg,Fe)_2SiO_4$	6 1/2	none	*vitreous	*olive to yellow-green	*white-yellowish	commonly in small glassy grains and granular aggregate	rarely a semi-precious stone
12	Epidote	Hydrous Ca, Fe, Al, silicate	*7	1 perfect	vitreous to earthy	*yellowish-green (pistachio green)	white or greyish white	earthy varieties show low hardness	-------
13	Kyanite	Al_2SiO_5	*4-7 (depending on crystal direction)	1 perfect 1 good	vitreous	*patchy blue also green, white or grey	white	elongated crystals, flexible and often twisted	refractories manufacture
14	Andalusite	Al_2SiO_5	7 1/2	1 distinct	vitreous or dull	white, grey *rose-red, brown	white	*coarse prismatic xls with nearly square cross-section	refractories manufacture (rarely)
15	Garnet	Ca, Fe, Al, silicate	7-7 1/2	*none	*vitreous	dark red, red-brown, green	white	*12-faced crystals	abrasive, gem-stone

LUSTRE: Non-metallic
HARDNESS: 2 1/2 to 6 1/2

No	Name	Composition	H	Cleavage or fracture	Lustre	Colour	Streak	Miscellaneous	Uses
16	Galena	PbS	2 1/2	*3 perfect at right	metallic	*lead grey	black	*s.g. 7.5 (very heavy) massive, granular, cubic crystals	ore of lead

No	Name	Composition	H	Cleavage or fracture	Lustre	Colour	Streak	Miscellaneous	Uses
17	Sphalerite ("blende")	(Zn,Fe)S	3 1/2 -4	6 highly perfect @ 60°	*resinous to sub metallic	yellow-brown to nearly black	*yellow to brown	*smell of H_2S on streaking	ore of zinc
18	Chalcopyrite	$CuFeS_2$	3 1/2 -4*	none	metallic	*brass-yellow	black to greenish black	distinguish from pyrite by lower hardness and colour	ore of copper
19	Pyrrhotite	$Fe_{1-x}S$	3 1/2	none	metallic	*bronze	grey-black	*usually slightly magnetic	often associated with pentlandite, a nickel ore mineral
20	Goethite "Limonite"	FeO·OH	3 - 5 1/2	none visible	dull to sub-metallic	yellow brown	*yellow or yellow brown	massive, porous, earthy	ore of iron (rarely)
21	Hematite	Fe_2O_3	5-6	none	dull to pearly to metallic	red to black	*red or red-brown	earthy, oolitic, massive, etc. Also metallic hexagonal-shaped crystals	ore of iron
22	Magnetite	Fe_3O_4 (often contains minor Ti and V)	5 1/2-6 1/2	none	metallic to dull	black to grey	*black	*strongly magnetic *s.g. over 5	ore of iron
23	Pyrite	FeS_2	*6 - 6 1/2	none	metallic	*pale brass-yellow	black to brown-black	*sometimes as cubic crystals, often striated granular, massive	manufacture of sulphuric acid (less important than previously

*denotes a diagnostic property

ANSWER SHEET -- MINERALS

1. Specimen #8 is MILKY QUARTZ.

2. Specimen #9 is AMPHIBOLE. Specimen #10 is PYROXENE.

   Don't be discouraged if you got the wrong answer. This is a very tricky test.

3. Specimen #8 has NO CLEAVAGE PLANES, and the surface should look like a series of small concave curves -- like sea shells, or pieces of broken bottle.

4. Specimen #23 has NO CLEAVAGE and NO REGULAR FRACTURE PATTERN.

5. Specimen #7 shows CLEAVAGE -- one well-developed cleavage plane & one poorly-developed

   Specimen #21 shows FRACTURE -- uneven fracture

6. Specimen #17 has a BROWN STREAK.

7. Specimen #20 has a YELLOWISH-BROWN STREAK.
   Specimen #21 has a REDDISH STREAK

8. Specimen #23 -- METALLIC LUSTRE
   Specimen #7 -- VITREOUS TO PEARLY LUSTRE
   Specimen #9 -- VITREOUS TO DULL LUSTRE

9. Specimen #17 won't scratch glass, so its softer than glass, but it will scratch the copper coin, so it will be somewhere in the 3.5 to 5.0 range of hardness.

10. Specimen #8 will scratch glass, so it's harder than glass. The knife won't scratch it, so it's harder than a knife blade. Its hardness is thus greater than 6.0.

11. Specimen #16 is HEAVIER than any one of the specimens from 1 to 15 of roughly the same size.

IDENTIFICATION PROCEDURE FOR SPECIMEN #7

12. Hardness Test: It will scratch glass, but the knife won't scratch it, therefore the hardness is 6.0 or greater.

13. Colour Test: creamy white, greyish, or bluish

14. Streak Test: white streak

15. Cleavage or Fracture: two well-developed cleavages at nearly 90° to each other. Possibility of a third cleavage.

16. Lustre Test: vitreous to pearly lustre

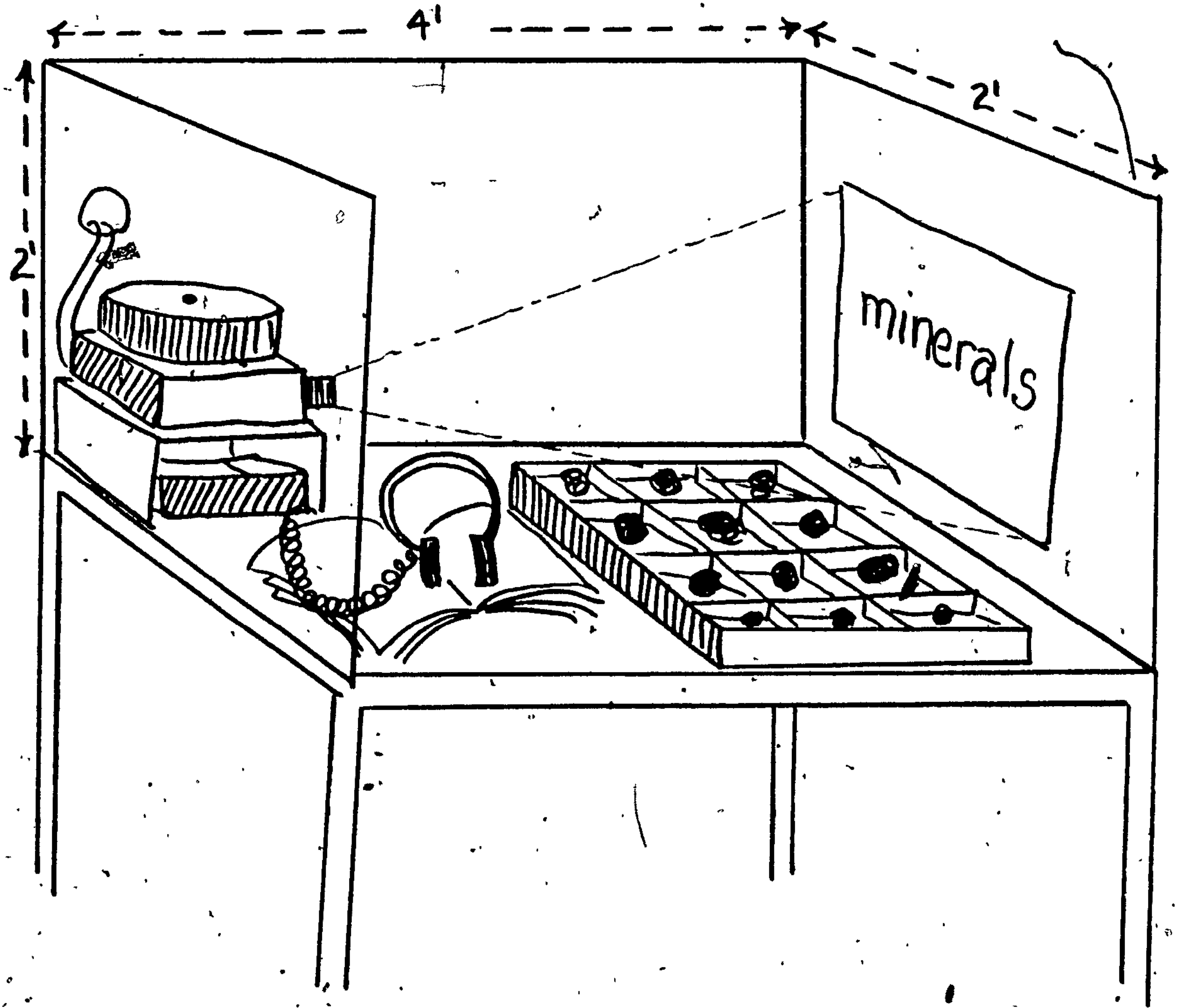
17. Specific Gravity: it's not heavy for its size, therefore it has a low specific gravity.

WORKSHEET FOR MINERAL IDENTIFICATION

Spec. No.	Hardness	Color and Streak	Crystal Habit	Cleavage or Fracture	Other Properties (Luster, specific gravity, taste, and so on)	Mineral Name and Compositio

APPENDIX D

Diagram of Audio-Visual Lab Carrel



APPENDIX E

Audio-Visual Lab Opinion Questionnaire

AUDIO-VISUAL LAB EVALUATION

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The a-v labs were interesting and kept my attention.					
2. After completing the a-v labs I found it easier to identify rock and mineral specimens.					
3. The a-v labs clarified things I didn't understand about rocks and minerals.					
4. After completing the a-v labs I had a better idea of what rocks look like in the field.					
5. The a-v labs were useful for review.					
6. The a-v labs didn't present any new information.					
7. The a-v labs were at the right level of difficulty for me.					
8. The slides of thin sections illustrated the concepts of texture & composition better than the hand specimens alone.					
9. I liked the music on the tapes.					
10. The lab demonstrators were sympathetic and eager to help.					
11. The a-v lab room should have been open more often.					
12. I like this way of presenting geology.					
13. The a-v labs helped me pass the lab tests.					
14. I would recommend that everyone use the a-v labs.					
15. The a-v labs increased my interest in geology.					
16. I preferred the regular labs to the a-v labs.					
17. The a-v labs were clear-cut and explicit.					

Please circle the appropriate answer(s). Use reverse side of page if necessary.

1. Why did you use the audio-visual lab(s)? (circle one or more)

   a) I missed the regular lab period and wanted to catch up.
   b) I find rocks and minerals interesting and wanted to learn more about them.
   c) I needed clarification of some of the points covered in the regular lab.
   d) I wanted to review for the tests.
   e) Other (please specify) ______________________________

2. Which audio-visual lab(s) did you do?

   a) Unit 1 -- Minerals
   b) Unit 2 -- Igneous Rocks
   c) Unit 3 -- Sedimentary Rocks
   d) Unit 4 -- Metamorphic Rocks

3. Were any concepts unclear in the a-v labs? If so, which ones?

   ____

   ____

   ____

4. What was your overall opinion of the a-v labs? Do you have any suggestions for improvement?

   ____

   ____

   ____

   ____

Thanks for taking the time to give us your comments.

APPENDIX F

Geology Attitude Questionnaire

Note: The first application of this questionnaire also included the following question:

Have you ever taken a geology or earth sciences course before? Yes ___ No ___

NAME ____________________
SECTION ________________

GEOLOGY EVALUATION FORM

EVERYONE PLEASE FILL IN PAGE 1. IF YOU USED THE A-V LAB THIS TERM, PLEASE FILL IN PAGES 2 AND 3 AS WELL.

Put a check mark in the column that best describes your attitude towards each of the statements below.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I like geology.					
2. I intend to take further geology courses after this.					
3. As soon as the exam is over, I'll probably forget everything I learned in this course.					
4. I don't bother spending much time on this course.					
5. I think this course is very interesting.					
6. This is an easy course.					
7. I expect to learn things from this course that will be useful to me later.					
8. This course bores me stiff.					
9. Geology is one of my favourite subjects.					
10. I'm only taking geology because I have to.					
11. This course is only usefu[illegible] those students who plan t[illegible] on in geology.					

12. What grade are you aiming for in this course? A ____ B ____ C ____ D ____

13. What grade do you think you'll get? A ____ B ____ C ____ D ____

APPENDIX G

Mineral Identification Test and Marking Scheme

STUDENT NAME AND INITIALS: ____________________

SECTION NO: ____________________

ROOM NO.: ____________________

GEOLOGY, 39-010

MINERALS SPOTTING TEST

10 minerals - one minute allowed for identification of each mineral, then pass counter-clockwise to next student.

No. of Specimen	NAME OF MINERAL (3 marks)	COMPOSITION (3 marks)	DIAGNOSTIC PROPERTIES (two required) (2 marks + 2 marks) = 10
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Mineral Test Specimens

Set 1 (Sections G and A)

1. Quartz
2. Pyrite
3. Orthoclase
4. Calcite
5. Biotite
6. Chlorite
7. Serpentine
8. Olivine
9. Limonite
10. Kyanite

Set 2 (Sections C, E and F)

1. Muscovite
2. Quartz
3. Pyrrhotite
4. Magnetite
5. Garnet
6. Orthoclase
7. Olivine
8. Limonite
9. Sphalerite
10. Serpentine

APPENDIX H

Lab Demonstrators' Questionnaire

1. What proportion of your time was spent answering questions from the students using the a-v equipment? From students who were not using the a-v equipment?

2. Were you able to cope alone, or do you think there should have been another demonstrator to handle the students who weren't using the a-v equipment?

3. Did the a-v labs appear to clear up the students' problems, or were they still confused at the end of them?

4. Was there any difference in the kinds of questions asked by the a-v students and the non a-v students? (i.e. did the non a-v students seem to be asking more basic questions?)

5. Were you able to control pilfering from the specimen trays?

6. Do you have any suggestions for improving the a-v labs next year? (i.e. better lighting? longer hours? separate rooms for the a-v and the non a-v students?)

7. Any other comments?

APPENDIX I

Audio-Visual Lab Opinion Questionnaire Results

AUDIO-VISUAL LAB EVALUATION (145 responses)

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1.	The a-v labs were interesting and kept my attention.	18%	55%	21%	4%	2%
2.	After completing the a-v labs I found it easier to identify rock and mineral specimens.	24%	57%	12%	4%	3%
3.	The a-v labs clarified things I didn't understand about rocks and minerals.	20%	54%	16%	7%	3%
4.	After completing the a-v labs I had a better idea of what rocks look like in the field.	7%	45%	31%	14%	3%
5.	The a-v labs were useful for review.	20%	65%	13%	1%	1%
6.	The a-v labs didn't present any new information.	3%	13%	16%	57%	11%
7.	The a-v labs were at the right level of difficulty for me.	6%	53%	29%	9%	3%
8.	The slides of thin sections illustrated the concepts of texture & composition better than the hand specimens alone.	9%	48%	25%	15%	3%
9.	I liked the music on the tapes.	29%	25%	28%	6%	12%
10.	The lab demonstrators were sympathetic and eager to help.	16%	52%	26%	5%	1%
11.	The a-v lab room should have been open more often.	16%	40%	40%	4%	0%
12.	I like this way of presenting geology.	17%	54%	24%	4%	1%
13.	The a-v labs helped me pass the lab tests.	20%	46%	20%	10%	4%
14.	I would recommend that everyone use the a-v labs.	19%	52%	26%	2%	1%
15.	The a-v labs increased my interest in geology.	6%	29%	43%	17%	5%
16.	I preferred the regular labs to the a-v labs.	6%	16%	32%	33%	13%
17.	The a-v labs were clear-cut and explicit.	12%	53%	27%	7%	1%