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Geological Education

Enseignement de la Géologie

MONTREAL, 1972

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Geological Education
Enseignement de la Géologie

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MONTRÉAL, 1972

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PREFACE

The 24th International Geological Congress has for the first time included a section on Geological Education in its technical program. This is a recognition of the growing interest in geological education and the desire to improve its quality and increase its accessibility.

During the past decade the Earth Science Curriculum Project in the United States has focused attention on the importance of including geology in the curriculum of students at pre-university levels. However, the response to the Congress program has shown that this interest in geological education for younger students is world-wide and by no means confined to North America. Also the papers show a remarkable similarity in the educational problems faced by geology teachers in many different countries.

In addition to the papers concerning earth science education at the pre-university level, there are papers relating to university educational problems and geological education in general. Teachers and all geologists wishing to encourage an interest in the earth sciences among young people will benefit from the experience and suggestions of their fellow geologists throughout the world.

We wish to express our thanks to Professor Robert Sabourin of Université Laval for the original organization of Section 17.

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PRÉFACE

Le programme technique du 24e Congrès Géologique International comprend pour la première fois, une section portant sur l'enseignement des sciences géologiques. Cette initiative confirme l'intérêt croissant que suscitent les Sciences de la Terre et le souci des enseignants de ces disciplines d'améliorer la qualité de leur enseignement et de le rendre accessible à un plus grand nombre.

Au cours de la dernière décennie le programme Earth Science Curriculum Project développé aux Etats-Unis a mis en relief l'importance d'inclure la géologie au curriculum pré-universitaire. L'intérêt soulevé par le programme du Congrès démontre que cette importance est également ressentie par nombre d'autres pays, ailleurs qu'en Amérique du Nord. Il appert aussi que les problèmes que rencontrent les enseignants de la géologie sont très semblables dans plusieurs pays.

En plus de communications traitant de l'enseignement des Sciences de la Terre au niveau pré-universitaire, le programme du Congrès contient d'autres travaux portant sur l'enseignement de la géologie universitaire ou sur l'éducation géologique en général. Les professeurs de géologie et tous les géologues s'intéressant à l'initiation des jeunes aux disciplines géologiques ne pourront que bénéficier de l'expérience et des suggestions apportées par la communauté mondiale des géoscientifiques.

Nous voulons exprimer à M. le professeur Robert Sabourin de l'Université Laval, nos sincères remerciements pour le rôle d'initiateur qu'il a joué dans l'organisation de la section 17.

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Earth Science Education at the Pre-University Level

Enseignement des Sciences de la Terre au Niveau Secondaire

Geological Education Today: Multiple Alternatives To Replace Linearity and Coercion

PETER FENNER and
WILLIAM D. ROMEY,
U.S.A.

ABSTRACT

In a multimedia demonstration, we seek remedies for the lack of alternatives for learning and the coercive nature of learning environments, two main factors responsible for the lack of geology enthusiasts at all levels.

Most geology courses involve linear programs that require all students to begin at a given point and then proceed lockstep through a lecture, lesson or activity. Because of differences in backgrounds of students, all material presented is redundant to several students in any class at any level. Curriculum reform projects during the 1960's represented significant attempts to depart from linearity by introducing guided inquiry techniques. Problems were externally posed, but in well-taught classes students were allowed to determine procedures to solve problems. Multiple outcomes and free, argumentative discussions were encouraged.

Linearity of rate is also imposed in most courses. Students begin and finish given units of work at specified times. This structure disallows meaningful digressions by individuals. Programmed instruction and audio-tutorial schemes are helping to alleviate this problem.

Externally imposed linearity is an anathema to creativity. Attempts are being made to develop non-linear activities in which individual students decide what to study, in what sequence, how, when, and for how long. Relevance is determined by the learner. Students emerging from these programs show disproportionately favorable attitudes toward geological subjects, high problem-solving abilities and have higher creativity. They will certainly perform better in "new curriculum" universities.

The coercive nature of existing programs becomes apparent in external, teacher-controlled or administrator-controlled grading and evaluation systems. Highly competitive programs lead students to be concerned with "beating the game" rather than their growth as scientifically literate human beings. Removal of competitive and coercive elements, where tried, has not led to a reduction of student activity, but has been accompanied by an increase in genuinely creative behavior.

ALMOST ALL THE WORLD'S EARTH SCIENCE AND GEOLOGY COURSES offered at pre-college and university levels are linear with respect to subject matter organization and the rate at which students are expected to progress.

Typically, students enter a course and begin their studies with a block of subject matter predetermined by either their teacher or an extrinsically imposed curriculum. Then they proceed lockstep through a set of lectures, laboratory exercises, recitations or other activities, generally keyed to a particular textbook.

Authors' addresses are given at the back of this book.

There is generally neither enhancement nor even cognizance of the uniquenesses that individuals bring to class as a function of their different backgrounds and experiences. Material presented, thus, is often redundant to some students even while it is way beyond the sensible grasp of others.

Two of the important curriculum reform projects which during the 1960's introduced the techniques of guided inquiry to help develop interest and motivation among pre-college students were the Earth Science Curriculum Project (ESCP) and Time, Space and Matter (TSM). ESCP, sponsored by the American Geological Institute, was the more conventional of the two programs, producing a textbook, "Investigating the Earth" (1967), a 2-volume "Teacher's Guide," laboratory kits, films and pamphlets. A linear approach was recommended in the ESCP Teacher's Guide, and most ESCP staff members promoted a basically linear approach during the testing and early implementation phases of the program. Students were to be treated in groups and were to be given group assignments with a carefully organized schedule enabling the group to cover all of the material provided. The presumption was that students who had covered the material had learned it. The guided inquiry approach did promote development of a new kind of classroom. Student-participation activities in well-functioning ESCP classrooms took up about half of the total class time. Laboratory activities and problems were externally posed, but, in well-taught classes, students were allowed to determine procedures to solve problems. Multiple outcomes and free, argumentative discussions were encouraged. In most of the best ESCP classrooms teachers were simply not able to cover the whole program. Teachers and their students in some classrooms became so engrossed in activities and arguments that many teachers became progressively more responsive to the needs of their students.

Students in classrooms where TSM was used found themselves in a less rigidly organized program. The curriculum-makers who created TSM prepared materials (1964-1968) that invited greater diversity of responses than did the ESCP materials. Very simple kits of materials and short pamphlets, some of them consisting largely of photographs to serve as materials for analysis, constituted the physical product of the TSM group. Students were invited to write their own textbooks. The notebooks of different students differed significantly. Still, the whole class jumped from topic to topic more or less in unison. Basic topic sequence and schedule were uniform for all students, regardless of their interests or optimal rate of learning.

Students throughout the world have begun to demand more individualized and personalized channels of study. Accusations of irrelevance, and complaints against large-group instruction and lockstep treatment have increased in number and volume to the extent of violent rebellion in too many schools.

A number of programs involving the offering of multiple alternatives to learners have begun to evolve at pre-university and university levels. Some of the first attempts to free learners from the linearity of conventional programs involved audio-tutorial (AT) and related systems of education (Fenner and Andrews, 1970). These allow learners to work at their own rate through an established curriculum. In well-developed AT programs such as those at Boston College, Ohio State University, Lansing Community College, Baylor University, and at numerous U.S. high schools, lectures and laboratory assignments are tape-recorded and laboratory materials are specially packaged so that learners may work individually at their own rate rather than in groups. Students, on an individual basis, go to a learning resource center where they enter a suitably equipped carrel and spend as much time as they need to work through a given packet of materials. Self-tests are a common component of audio-tutorial packets; they tend to reinforce learning and may determine when learners have met a predetermined standard. Small-group discussions and large-group lectures are usually a part of the learning environment, but the student is normally held accountable mainly for what he has learned from the AT part of the program.

Redundancy is greatly reduced, in that students who have prior knowledge in a given area can skim a lesson and leave almost immediately or work ahead on enrichment work or advance lessons. On the other hand, students having trouble can spend as much extra time as they wish in mastering a block of subject matter and can seek extra help from instructors usually on duty in the learning resource center.

Numerous studies have confirmed that students learn as much or more in audio-tutorial programs as they do in conventional programs and that in general they prefer the relatively relaxed AT program to conventionally organized courses.

The assumption made in these studies is that the AT courses are well designed. Sections of the publication by Fenner and Andrews (1970) are devoted to the design of AT courses, with examples and histories given, and to some of the major pitfalls and dangers with which AT systems may be fraught.

Attempts to give students more alternatives as far as subject matter is concerned have led to the development of minicourse systems (Romey and Dean, 1971). In these programs several instructors may team up to provide a number of simultaneous short courses, commonly of 3 to 5 weeks' duration. The student selects one of these. Once in a minicourse the student is generally confined to a lockstep program; however, he may have options concerning time requirements for completion of the minicourse. Addition of AT minicourses or of independent study options increases the potential number of alternatives available to students. Examples of these and related options are analyzed in a useful publication by biologists Creager and Murray (1971). That publication includes a statement by the Postlethwait group (Hurst and Postlethwait, 1971) that is interesting because it indicates the evolution of ideas from the original wellspring — Postlethwait being the father of AT systems.

The maximum number of alternatives and rejection of linearity (externally imposed) are possible in what are being labelled open, student-directed or student-centered learning environments. In these, students are allowed to choose virtually any topic for study and may pursue the topic to any reasonable depth desired, within the limits of the resources that can be made available. The teacher occupies a role of tutor or advisor in an open classroom rather than being a presenter of information or an enforcer of discipline. In most schools, such open classrooms are available in single subjects so that a learner is still expected to work on his earth science during some pre-specified hour each day whether he is in the mood for it or not. Thompson (1970), Hudiburg (1971), Crowley (1971) and others have described their experiences in open, pre-university classes.

In a few places, entire schools operate along the open lines described above. In such schools, students at any age level may opt to study earth science subjects whenever and to whatever extent they wish to do so. The Wilson Campus School (Thompson, 1970) in Mankato, Minnesota, and the Eagle Rock High School in Eagle Rock, California, are two pre-university schools in which earth science is an important offering in a total open-school setting.

Special materials to help teachers make a transition into open-classroom learning models have been produced by the American Geological Institute's Environmental Studies Project. These materials are being tested and evaluated in elementary and secondary schools in several major cities in the U.S. Early evaluations of these materials indicate a significant increase in creative behavior of students, an increase in scientific as well as ordinary literacy, an increase in self esteem among teachers and students, and an improvement of attitudes toward learning.

Several new-curriculum universities have begun to implement programs that provide multiple alternatives to learning — as opposed to linear programs. Two of these are Governors State University and St. Lawrence University, with which the authors are affiliated.

At Governors State University, which is devoid of departmental structure, an extensive set of performance objectives has been established for students enrolled in the College of Environment and Applied Sciences. Students select for themselves the ways in which they will satisfy some of those listed objectives and others which, together, define the individualized program dictated by students' needs. Learning modules, rather than courses, are being developed to help students focus on certain performance objectives consonant with their own goals. Thus, performance-based objectives are developed by students and faculty, and then serve as goals in which mastery is emphasized. The learning modules typically are interdisciplinary and designed for students to work side-by-side in small groups or alone. Completion time and credit are variable; the threats associated with competitive grading are removed by obviating grades: a student's transcript will therefore reflect only work that has been completed — at a level of competence specified in advance. All learning modules involve more than one staff member, and are designed to deal with social and humanistic consequences of their scientific and technological content. Self-paced, socially relevant, problem-oriented work thus sets the stage for students to acquire the ability to conduct research while gaining cognitive skills, and to acquire a societal value-orientation while they add to and draw from the world's data pool.

At St. Lawrence University, the Department of Geology is organized as a learning community. There are no conventional full-time courses. Each student, from freshman through senior, develops his own personal program of study. A student may study topics in the area of the earth sciences in whatever sequence he chooses, in whatever way he chooses, to whatever depth he chooses, with whatever colleagues he chooses, and for as long a time as he chooses. Faculty members act as counsellors, advisors and co-learners. Students grade themselves. Faculty members and peers obligate themselves to provide regular feed-back and evaluation to provide each student with their own opinions of his work, but no relative rankings or numerical judgments are made. Informal short courses develop when enough students request them and last only as long as the members of a given *ad hoc* group remain interested enough to attend by their own initiative. Students with greater knowledge and experience in certain areas also teach students with less knowledge when the latter request such help. Thus, faculty and student members of the community act as learners and teachers at various times. The model is that of a research laboratory rather than a school. Large-scale ongoing departmental research projects provide beginning students a chance to become apprentices or research assistants on a short- or long-term basis as they learn to cope with the freedom and multiple alternatives provided within the community. Participation in the long-term departmental projects is certainly not required, but it does help many participating students make the sometimes difficult transition from extrinsically structured, linear programs to independent studies of their own design.

Students emerging from primary and secondary school programs that provide multiple alternatives which promote diversity, originality, high problem-solving abilities and decision-making capabilities will certainly perform better in the increasing number of new-curriculum universities. There is also good evidence that students trained in this manner also function as well as or better than students trained in the conventional system even when they enter universities with a rigid curriculum (Chamberlin, *et al.*, 1942). We believe, further, that practice at decision-making also prepares students for ordinary decision-making in the after-university life in a way that ivory-tower studies simply cannot.

The system of evaluation used in conventional schools may for many, or even most, students strongly inhibit learning. The coercive nature of existing conventional programs is apparent in external grading and evaluation schemes controlled by teachers or administrators. Learners have begun to rise up against competitive grading systems that pit one student against another. Optimally, learning should be a venture that fosters cooperation and exchange of ideas and resources among learners. Highly competitive programs have been shown by many investigators to have a detrimental effect on learning, especially among students who have not discovered how to cope with the system (Kirschenbaum, Simon and Napier, 1971). Many students who are successful in school have merely learned to beat the game better than their academically less successful peers and, functionally speaking, have actually learned little if anything more than their peers.

The goal of pre-university and early university-level education in the earth and other sciences should be to help learners grow as scientifically literate human beings who aspire to functional citizenship. In order to get rid of pressures that clearly inhibit learning among students, many teachers and some schools have recently introduced self-evaluation and self-grading, credit - no report systems, blanket high-pass grades or no-grade systems. Removal of competitive and coercive elements, where tried, has not led to a reduction of student activity, but has actually led to an increase in real learning and an increase in creative behavior (Kirschenbaum, Simon and Napier, 1971; Earth Science Teacher Preparation Project, 1972).

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An Earth Science Program for the Primary Grades (Kindergarten to Third Grade)

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ABSTRACT

Noting that the interests of primary school age children (grades K-3) focus strongly on such topics as rocks, dinosaurs, volcanoes, weather, moon and stars; and further noting that the new elementary school curricula as developed for the primary level make relatively little use of earth sciences content, we have attempted to identify appropriate experiences in the earth sciences for children. The program incorporates the following: science educational process applicable to the primary grades, pre-operational and concrete-operational Piagetian child development considerations, sequentially planned activities and varied strategies. The program covers four general topics: Landforms, the Moon, Fossils, and Weather. Activities have been classroom tested. The format for each topic includes a teachers guide, student sourcebook and the necessary materials. The activities within each topic are described here — each paragraph being a separate lesson.

LANDFORMS

IN THE FIRST LANDFORM LESSON, the children are introduced to accumulational landforms through films, pictures, fieldtrips or models. They discuss the similarities and differences among such features as talus slopes and cones, deltas and dunes; and learn the names given to these structures. These are then compared to the shapes of wind and water ripples and alluvial fans. From this activity, they are asked to propose a hypothesis for fore-slopes found on these accumulational landforms. The lesson may be reviewed, following the next lesson in this series, for reinforcement of the conclusions formed in both.

We start the next lesson with a discussion of sand dunes that the children have seen. They then pour sand and gravel into separate piles on the tops of their desks, and observe, describe and record the slopes that are formed. Questions are raised as to the effect of particle color and size, amount and method of pouring on the slopes obtained. As hypotheses are formed they are asked to test these in any way they want, arriving finally at a conclusion concerning the subaerial angle of repose. The students are then asked how the slope of material deposited as a delta might be developed. As they experiment with sediment carried by running water into a standing body of water, they again observe, describe and record the slopes. Further discussion of these slopes, plus weighing a rock in air and in water, leads to a conclusion concerning the subaqueous angle of repose. Slopes of talus cones, deltas and dunes

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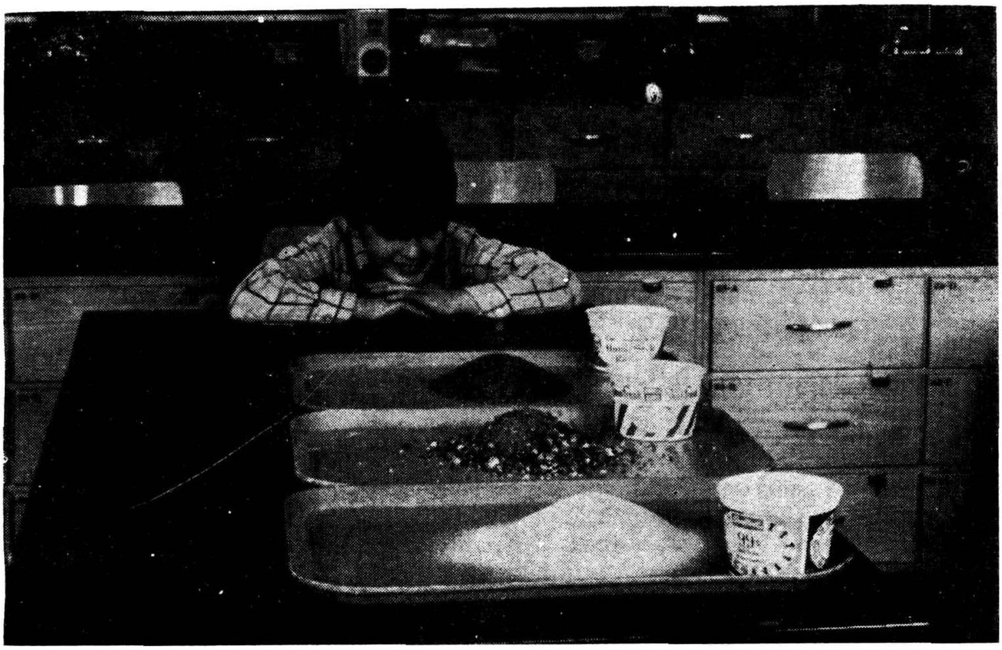

FIGURE 1.

are compared in light of these newly formed conclusions; and the children delight in indicating the type of slope to be found on a sand dune in the Sahara desert or a delta in the Caspian Sea, both distant places that they find on a world globe (see Figure 1).

Turning to volcanoes, the children view films, pictures or models of shield, composite and cinder cones together with typical hand specimens from each. A period of discussion raises various hypotheses as to their different modes of formation. A film or ammonium dichromate model graphically illustrates that in the case of the cinder cone it is the angle of repose, which they readily recognize. Another film, or working model, of pillow lava is then observed and discussed. This is followed by a free play period with the children blowing soap bubbles and describing the shape of the tops and bottoms of individual bubbles in a cluster. Then, using drinking straws, the students blow air into a thick plaster of paris mixture, and compare the results with vesicular basalt. We then pose the problem of how geologists can tell if a series of old lava flows is upside-down or right-side-up. Various proffered hypotheses quickly lead to the conclusion that the air bubbles and/or rounded pillow forms are indicative of the original top of the flow.

Rock classification begins by distributing nine hand specimens; sandstone, arkose, conglomerate, granite, felsite porphyry, gabbro, phyllite, schist and gneiss. After hand-lens examination of these, the students are asked to put them into piles of the same kind. Any number of piles or groups will do. Then we discuss how many piles were made, and why? What was grouped together? All ideas are stated and discussed. Then the children are asked to group the nine rocks in only three piles. Again their reasons are discussed. Through continual discussion and rearrangement they generally arrive at putting all the "pieces" (sedimentary), "glassy bits" (igneous) and "flat-lying" (metamorphic) rocks in the right groupings. Some terminology may gradually be introduced here, though memorization of it is not required.

Structural geology is developed through the construction of sandwiches, an enjoyable activity that can be varied to accommodate local taste and custom. Laying a slice of bread on a table the students proceed to add a slice of ham, a slice of cheese, a layer of lettuce, then top them all with another slice of bread. The children are asked which layer of the sandwiches was put down first, last and in the middle of the series. The ham can be "dated" as following the first slice of bread but preceding the cheese. The concept can be developed further by adding more layers, making what we in America call a double- or triple-decker sandwich. Cross-cutting relationships are reached through examination of the toasted area surrounding a hot metal rod (a soldering iron) pushed up vertically through the sandwich layers, the burnt layers obviously being relatively older. Horizontally placing of the hot rod leads to conclusions that it was intrusive if the lower and upper surfaces of adjacent layers are toasted, but extrusive if only the upper surface of one layer is so marked. Slicing the whole sandwich and moving the two halves vertically or horizontally develops hypotheses by the children concerning relative motion along a fault scarp.

Making and eating candy always finds enthusiasm among children. The basic recipe is 2 cups of granulated sugar, 1 cup of water, a pinch of table salt and 1 teaspoon of vanilla extract. Those who wish can make a dark candy through the addition of 2 tablespoons of cocoa. Heat and stir until a drop of the mixture forms a ball or bead in cold water. We ask the children how their hot solution should be cooled down, quickly or slowly, and end up with different groups doing one or the other. Quick cooling is accomplished by pouring the solution into a wide shallow dish or pan; slow cooling is obtained by putting the heating beaker or saucepan into a hot-water bath to cool down. When all the candy has cooled pieces are distributed for observation. The children conclude that light or dark candy is formed depending on the ingredients that went into the recipe. Correlating the fine and coarse texture that they find with rates of cooling takes some testing of hypotheses, but the conclusion is usually apparent. Given the following four igneous rock hand specimens the children either group felsite and granite versus basalt and gabbro on a color-composition basis, or felsite and basalt versus granite and gabbro on a textural basis. Learning the names of the rocks is not particularly important here.

The final activity in this series begins with the examination of an outcrop or large specimen of granite or diorite; though the instructor can adapt other available local types to this use. With the aid of hand lenses the children describe the particles making up the rock. Thus they find that rocks are made up of smaller pieces that they might guess are "atoms", "chemicals" or even "minerals", depending on their vocabulary. They are then given an array of mineral specimens (calcite, quartz, magnetite, galena, pyrite, halite) and some equipment (magnet, copper coin, metal nail, piece of glass, streak plate) to play with. After a while we ask the children what things geologists can use to recognize different minerals. They propose such physical characteristics as weight for size, color and streak, flat sides, hardness, magnetism and taste, plus other ideas that may be discarded by their classmates. We then ask them to find: halite, which can be scratched by the copper coin and tastes salty; magnetite, which is heavy and is attracted by a magnet; pyrite, which is gold in color but has a green or black streak. The learning of mineral names here is not as important as the process of recognition.