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Background Study 52

Science Education in Canadian Schools

Volume III
Case Studies of Science Teaching

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Volume III
Case Studies of Science Teaching

Edited by
John Olson
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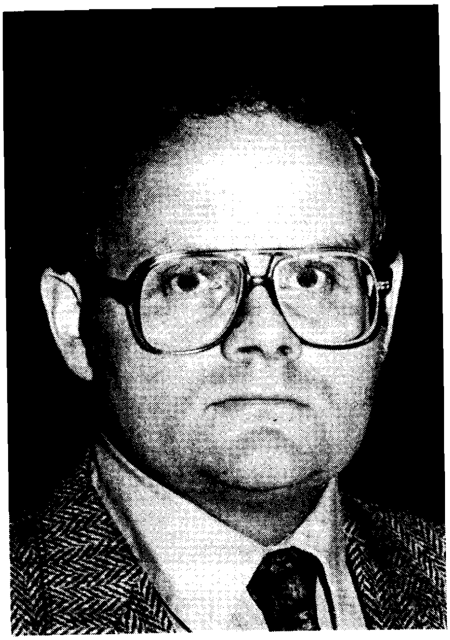

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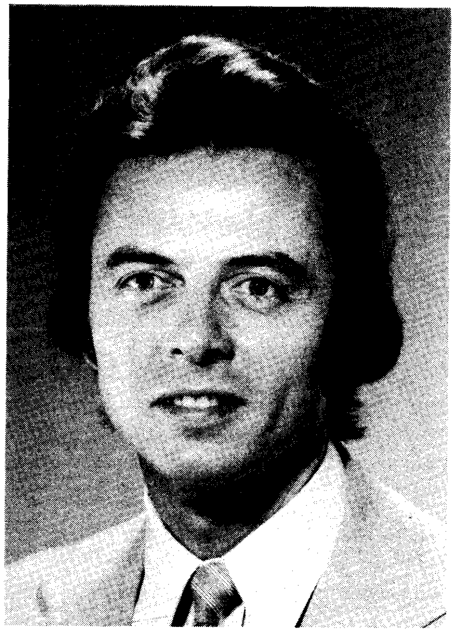

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Foreword

Excellence in science and technology is essential for Canada's successful participation in the information age. Canada's youth, therefore, must have a science education of the highest possible quality. This was among the main conclusions of the Science Council's recently published report, *Science for Every Student: Educating Canadians for Tomorrow's World.*

Science for Every Student is the product of a comprehensive study of science education in Canadian schools begun by Council in 1980. The research program, designed by Council's Science Education Committee in cooperation with every ministry of education and science teachers' association in Canada, was carried out in each province and territory by some 15 researchers. Interim research reports, discussion papers and workshop proceedings formed the basis for a series of nationwide conferences during which parents and students, teachers and administrators, scientists and engineers, and representatives of business and labour discussed future directions for science education. Results from the conferences were then used to develop the conclusions and recommendations of the final report.

To stimulate continuing discussion leading to concrete changes in Canadian science education, and to provide a factual basis for such discussion, the Science Council is now publishing the results of the research as a background study, *Science Education in Canadian Schools.* Background Study 52 concludes, not with its own recommendations, but with questions for further deliberation.

The background study is in three volumes, coordinated by the study's project officers, Dr. Graham Orpwood and Mr. Jean-Pascal Souque. Volume 1, *Introduction and Curriculum Analyses,* describes the philosophy and methodology of the study. Volume I also includes an analysis of science textbooks used in Canadian schools. Volume II, *Statistical Database for Canadian Science Education,* comprises the results of a national survey of science teachers. Volume III, *Case Studies of Science Teaching,* has been prepared by professors John Olson and Thomas Russell of Queen's University, Kingston, Ontario, in collaboration with the project officers and a team of researchers from across Canada. This volume reports eight case studies of science teaching in action in Canadian schools. To retain the anonymity of the teachers who allowed their work to be observed, the names of schools and individuals have been changed throughout this volume.

As with all background studies published by the Science Council, this study represents the views of the authors and not necessarily those of Council.

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I. Themes and Issues: Introduction to the Case Studies

John Olson and Thomas Russell

The Design of the Case Studies

Would-be critics and reorganizers of the educational system must attend to the important lessons that emerged from the school curriculum reforms of the 1960s. Although these reforms affected most school subjects, their influence was particularly strong in science. Curriculum developers seemed to expect that new ideas for teaching science could and would be implemented much as they had been designed. However, the research studies that followed revealed that classroom events were more complex and teachers less able to change than had been expected. At the same time, these studies seemed to show that innovative curricula were "better" than traditional ones, but only because the criteria used to evaluate them unintentionally favoured the former. Generally, students learned best whatever their teachers emphasized.

The importance of the way science is emphasized by teachers has been noted both by critics of science education and by curriculum theorists in Canada. Criticisms tend to focus not on the content of science courses but on the way the content is treated, particularly on the apparent lack of an emphasis either on the history of Canadian science or on the relationship between science and technology in Canada. These case studies are designed to explore the emphasis that teachers *do* place on the subject matter they teach. In exploring these emphases we recognize that science teachers play a central role in determining what can and does happen in the classroom. In planning and conducting their teaching, teachers bring into action the particular frameworks of thought and belief that they hold. Teachers' curriculum emphases can be inferred directly from classroom events, but to assess the validity of inferences about practice and to understand the reasons why particular emphases are adopted, it is also necessary to explore, through dialogue with teachers, the frameworks of thought and belief about education that underlie classroom events.

The case studies reported here were done in eight locations across Canada. Each site was studied by a person possessing both the necessary research capabilities and appropriate background knowledge of science education in the region. Over a period of several months, site visitors compiled observational and interview data and analyzed documents, using approaches they developed at a planning conference preceding the field work. The case-study research group included Glen Aikenhead, Lawson Drake, Jim Gaskell, Brent Kilbourn, John Olson, Pat Rowell, Tom Russell, Mary Schoeneberger and Pierre-Léon Trempe. Graham Orpwood, from the start, was associated with the work as a sympathetic adviser and critic.

Sites for intensive study were selected to include a diversity of both regions and school settings. At each school site, various kinds of information were collected — for example, information concerning what went on in the classroom, the documents used by the teachers, what teachers said about their work — to obtain as complete a picture as possible of how science is taught. As observation proceeded, emerging hypotheses were checked, modified and developed further. Such direct access to sites has been important because the data that have been collected are sufficiently complex and the meanings to be inferred from them sufficiently uncertain that it has been necessary for the researchers to observe the events of the classroom themselves and to discuss those events with teachers. This approach to the problem was chosen after several alternatives had been considered.

In order to review the "state of the art" in case-study methodology and discuss what common starting points might be valuable in the study, the research team met for four days in February 1981. Emerging from that conference, for consideration at each of the sites, were a number of issues related to what happens in the classroom and to how teachers interpret classroom events and other aspects of school life. The case studies were to focus on the events of science teaching as they are influenced by the teacher, by written materials and by other factors in the classroom environment. These events were to be analyzed to determine the emphases teachers place upon the subject matter, the ways in which teachers socialize their students, and the interaction between these two factors. Finally, teachers' intentions concerning their teaching activities were to be explored to determine what factors in the educational environment they perceive as shaping classroom events. Discussion of how to implement these ideas formed an important part of the preliminary meeting.

A number of principles of procedure have guided all of the researchers. These were discussed at great length at the preliminary meeting and have formed the practical context in which these studies have been conducted. These principles involved ways of choosing sites, ways of gaining access to them, ethical guidelines for our work with individual teachers and similar matters. The following principles of procedure were established for all eight case studies. School personnel we talked to were to be informed that they could, without any malice, discontinue their participation in the study at any time. They were to be informed that they had the right to see what was written about them and to correct inaccuracies in any factual statement about them, to review interpretations about them and have alternative interpretations printed in the final site report and, as a last resort, to have facts and interpretations about them removed from the site report.

As research got under way in the fall of 1981, we visited each of the sites in order to compare notes, act as a sounding board and help identify problems early in the research. A number of methodological issues emerged from these visits and these were collected together in the form of a report to the research team. When the research team came together again in June 1982, some 16 months after the original planning meeting, it tried to determine what the cases said collectively about the work of science teachers.

It became clear at the outset that we had to recognize the different levels of teaching within the school system. There was little doubt that there were important differences in curriculum, in teaching and in the teaching environment at different levels. Early-, middle- and senior-division teachers seemed to work in quite different "universes," and we felt it dangerous to assume that the categories we might use to talk about the work of senior teachers would apply, for example, to teachers of the early years. In addition to great variation in teachers' knowledge of subject matter and available resources for teaching science, there is diversity in the educational goals different divisions strive to achieve. These overall goals and their embodiment in practice form a context that influences the way science is taught.

To summarize these comments, we find we must attend to how the subject of science fits into the working life of the science teacher. The case studies show that, in practice, teachers are concerned with maintaining their credibility, exerting their influence, gaining access to scarce resources, coping with conflicts between outside expectations and the realities of the classroom, coping with a lack of skill to teach science as innovators imagine it should be taught, fulfilling the expectations of authorities and resolving conflicts between students' interests and the demands of the subject.

We found a complex web of interacting factors present in the way teachers approach their work. Our task in what follows is to clarify the nature of the teachers' thinking about those factors and to identify the underlying and persistent concerns that seem to rule the way teachers resolve the tensions in their work. By combining knowledge about the decisions that teachers make, the frameworks in which they make them and the factors that influence teachers, we believe we will be in a better position to construct pictures of how science is being taught in the school contexts we studied, and to appreciate why teachers act as they do in their classrooms. We hope these case studies, by illuminating for decision makers the demands and dilemmas that teachers cope with in everyday classroom activity, will yield some hint of what might happen if particular practices of teachers are subjected to pressures for change. If we can help decision makers appreciate the possible consequences of upsetting some of the delicate balances teachers create to cope with teaching as an occupation, then we shall have made a contribution to the deliberation about futures for science education in Canada.

The Case Studies: Major Themes

The comments that follow are intended to help the reader locate areas of interest within the separate case studies. The comments here are divided into three parts, reflecting three broad divisions of elementary and secondary schooling. We designate kindergarten through grade 6 as the *early years* of a child's education, grades 7/8 through 9/10 as the *middle years* and grades 9/10 through 12/13 as the *senior years.* (Some variation is necessary in the boundaries, to recognize provincial variations across Canada.) From the case studies in each division we have isolated major themes which have become the basis for the organization of our comments about that division. While examples that illustrate the themes may be drawn from one or another case, each comment is made with all of the schools within the division in mind. Further, we have related information about what goes on in classrooms to information about the context within which that work takes place and to what teachers say about the work. In this way we have tried to relate what teachers say about their work to what we have observed of that work in their classrooms.

Clearly, our analysis of the case studies involves making judgements about what the significant events of the science classroom are, about how they are related to the account of them given by the teacher and about the interpretations provided by the researchers. We hope that readers will be tempted by these comments to explore the cases in detail and to test our rendering of them against their own personal impressions. The following discussion of the eight case studies could be read as a generalization, but it would be very inappropriate to interpret our comments as a set of generalizations about science teaching across Canada. Our purpose is to identify possible relationships among events that were recorded in the eight cooperating schools. We highlight themes and issues, hoping thereby to provide a guide for the reader who goes on to examine other science teaching situations with which he or she is familiar. Likewise, the research group that prepared these case studies has developed and applied ways of looking at people and events in eight schools in the hope that similar ways of looking at science teaching will be useful to others.

As we begin this discussion, we would like to express our thanks to the teachers who participated in the case studies. We hope that we have read sympathetically these cases which document their practices; our effort has been to understand how teachers approach their work. The work these teachers do is complex, and these studies are but preliminary glimpses of the science classroom.

The Early Years

Two studies, Seaward and Part II of Trillium, provide data relevant to the early years, a period of schooling in which approximately 10 per cent of the available time is allotted to the study of science. A subject that occupies a small fraction of total curriculum time understandably presents a task different from that facing the teacher in the middle or senior years, where those who teach science usually teach it for most of each day. Science demands preparation time, access to equipment and confidence. Unfortunately, a "10 per cent concern" is not likely to build teachers' confidence through experience, at least not in the short run, as the teaching of science in the early years is such a small part of the daily teaching load.

Two of the early-years teachers were attentive to children's curiosity about phenomena that science can explain and to the differences boys and girls show, as groups, in their attitudes to science. Perhaps the latter portion of the early years is the time when significant attitude differences emerge clearly in patterns that may persist for a lifetime. Early-years teachers spoke of the importance of young children's interests and of the opportunities that arise, over the course of a school year, to pursue children's science-related interests. For example, dinosaurs are a common science topic in the first year or two of school; guinea pigs, gerbils and fish are familiar animals in the classrooms of those teachers who are prepared to do the work required to maintain the animals. One teacher has introduced a computer into his classroom and found that it attracts the attention of the boys who show interest in science, a group he has resolved to challenge rather than settle for "mediocrity" throughout his class. The reader who is unfamiliar with teaching in the early years may find helpful the account of a "typical day" which concludes the discussion of science at Seaward.

In the early years, as in the middle and senior years, teachers feel the pressure of time. Some teachers respond to this pressure by integrating science with related topics in other curriculum areas. For one teacher, this is not avoiding science but linking it with other aspects of the curriculum, as an aid to teaching effectiveness and making the best use of time. Teachers at this level must balance their "time budget" in ways that teachers in the middle and senior years do not. To those outside the early years, integration may seem to be a "softening" of science experience in those grades, but the nature of the intended integration can only be judged by talking with and observing the teacher who claims to use such an approach. The matter of integration and its impact on science work in the later years is an important issue for science curriculum planning.

Within their schools, the four teachers of science in the early years who were observed tend to be isolated, not by choice but by circumstance and tradition. Cooperation with other teachers is difficult to arrange and maintain. The presence of a "science expert" in a school appears not to be an effective way of disseminating ideas about the teaching of science. In one case, teachers found that workshops and materials from outside the school were helpful in building the confidence they now display in the teaching of science.

The Middle Years

Three studies focus on the middle years – Northend, McBride and Part I of Trillium. Middle-years teachers lay particular stress on "covering the material" in the time available. "Covering the material" means ensuring that the "correct" explanation is included in the students' notes. At Northend, for example, where the stress is on following instructions supplied by lab procedures in the textbook, notes were given followed by "illustrative" work in the lab. "Good" diagrams were based on the text, not on actual data collected, as in the case of the ray diagrams used to show the reflection of light.

At McBride, activity sheets were produced by the head of the department and used by the other teachers. The sheets contained instructions for carrying out procedures in the lab, which were followed primarily by recall questions reviewing terminology. Filmstrips, used extensively in conjunction with the activity sheets, similarly stressed technical vocabulary. Students copied the information from the activity sheets into their notebooks, the text being used mainly as a "resource." At Trillium, too, the work was controlled by chalkboard notes or handouts; the text remained a resource for occasional use. Here, also, the emphasis was on "correct" terminology and making sure that students had the "approved" definition in their notes.

The impression left by these middle-years schools is that of a considerable body of material to be "covered." Central to covering the material is a stress on the specialized vocabulary of science, access to which is controlled through notes and activity sheets designed by teachers. Lab work is also based on teacher handouts or on procedures from a text. Following procedures and recalling terminology are central activities of the science lessons in these middle-years schools.

All the middle-years teachers stressed nonacademic aspects of their teaching life that they felt contributed to their effectiveness with the adolescents they work with. At Northend, where the teachers have degrees in science, the stress is on the subject, but some effort is given to making the subject "connect" with students' lives. Teachers there said they wanted to increase the relevance of their courses but indicated that there were pressures preventing this. The science teachers at McBride played important roles in the wider social activities of the school. They said that their extracurricular activity was important, and they emphasized the acquisition of social "skills" — such as responsibility — through learning routines in the science classroom. At Trillium, science happenings (collected by students in the form of newspaper clippings) and science fairs were used to promote interest in science and to show that there was a connection with "out there." In doing the science fair work, the students were seen as practising the "scientific method."

When teachers spoke of their work, the pressure of time was cited as a significant problem. At Northend, teachers found that marking and preparation were time-consuming, and that the semester system created a pressure to get through material. As a result of the time pressures, the teachers said, they could not include much material on science-society issues. Covering the ministry-prescribed material contributed to the sense of strain these teachers felt. At McBride, the ministry's guidelines required teachers to cover a large amount of material; for one teacher, this meant there was no time for "whole-class" discussions. Similarly, at Trillium, efficient use of time was uppermost in a teacher's thinking about what to teach; lack of time was a reason for not including more lab and field work, because covering the vocabulary of the subject required all the time he had.

Students' interests and correct behaviour concerned these middle-years teachers. A Northend teacher spoke about the extra energy needed to teach middle-years students; similarly, at McBride, the lack of student manners, particularly among nonacademic stream students, was bothersome. At Trillium, the teacher was concerned that students not treat the practical work flippantly. He remarked that if there were signs of misbehaviour during lab periods, students' work was halted and a demonstration given instead: direct experience was withdrawn from students as a punishment for misbehaviour.

These middle-years teachers made it clear that their students were not easy to teach; class control was a central concern, and trying to interest students was a high priority in their planning. Teachers at Northend, for example, spoke ruefully about the lack of students' interest in the labs they did, and about how hard it was to engage the students intellectually. At McBride, the teachers spoke of their concern for helping students feel "comfortable" with the subject. And at Trillium the teacher was concerned with reducing students' fear of science, a fear that he believes is a consequence of teachers' attitudes to science in the early years. He encouraged the students to express their feelings about him and about their work. While these teachers gave class control a high priority, they remained unsure about the inherent interest of the work they had students do, work which might have improved control by engaging students' interests.

The middle-years teachers stressed the importance of routines and of standards of accuracy and thoroughness to which students should adhere. Accuracy is at the heart of what they believe to be a "scientific" approach to problems. At Trillium, the teacher was adamant about thorough copying of notes and complete answering of assigned questions, but did not worry about the writing-up of experiments which, he felt, could come later. Good notes, which would make review for tests easier, were emphasized. In his view, these notes laid the groundwork for the next grade. Teachers at McBride said that learning to follow routines prepared students for grade 9; accuracy of diagrams in students' notes reflected the "experimental" process and eased review for tests. Northend teachers, also, stressed the importance of preparing students for the next grade; making sure that the "correct" answer was entered into the notebook was part of establishing a base for further work.

How might we interpret the strong focus of these teachers on orderliness, routine, procedures and "approved" explanations? This emphasis on the certain, the exact, the "right" answer, contrasts with an emphasis on the process of inquiry and the conceptual and tentative status of knowledge in science. First, we have to consider the amount of material these teachers are asked to cover; by their own report, it seems extensive. Given also that the material is presented as a body of facts with a strong "official" emphasis on terminology, it is not surprising that teachers treat it as a commodity to be delivered. Second, the subject matter is the main vehicle for engaging students' interest and for channelling their energies in approved directions. Again, by their own account, channelling students' energies is not an easy task for teachers. How do these teachers accomplish this task? Thorough and accurate note-taking and routine are stressed, copying from activity sheets and from the chalkboard appears to be common, and, where labs occur, correct procedures and recording correct information in notebooks are emphasized. Such highly predictable activities are valued, ostensibly because they will allow material to be easily reviewed for tests and because the information so accumulated provides a base for work to be done in the next grade. These activities control and channel students' energies because students are kept busy doing routine, unambiguous work. Third, the teachers tend to use their own materials to guide activity and provide a context for that activity. Teaching from the text is not predominant; teaching through note-giving and procedure-following, is.

The official documents supplied by the ministries of education influence both the nature of the material presented and, less directly, how that material is presented. The classroom work is seen by middle-years teachers as fulfilling the mandate given to them by the writers of the curriculum documents, and, at the same time, as ensuring that students will be prepared to move on to the next grade, ready to tackle the work prescribed for them. The orderly habits engendered by the following of routines are justified by the teachers because they will help students to complete their grades and because they let students experience, if only for a moment, what it might be like to be a scientist.

The pressure of time is cited by teachers as a reason for not introducing into a well-ordered and coherent system any activity that might upset the smooth running of things as they are. The prevailing system gives teachers purpose and direction, channels students' behaviour in desired directions, and enables students to complete grades successfully and move smoothly to higher grades.

However, the problem may not be lack of time for alternate methods and subject matter. It may be that teaching early adolescents and selecting appropriate content is difficult (especially for nonspecialists). Perhaps teachers find that strict adherence to legitimate and well-defined content specified by ministries of education is a secure base upon which to build notes, lab procedures, teaching strategies and examinations. To do so may seem "safer" to teachers than emphasizing the processes of science or science-society relationships.

One might argue that very restricted use is made by these teachers of the potential that the study of science has for general education, especially for learning about the role of science in society and in technology. While these teachers tap this potential to some small extent, perhaps more than they are encouraged to do by the way their instructional mandate is formulated in the official documents they receive, it may be less than their students might wish and less than they ought to do, given the ways in which society is changing and the demands it will soon make on their students. Arguments on both sides of this issue can and have been made. We hope that these case studies will stimulate further debate, informed by teachers' views on these matters.

Those who would alter the middle-years science instruction system must consider the effect of innovation on the persistent problems faced by middle-years teachers, especially those who are not science specialists. How would these changes affect the existing relationship among teacher, students and curriculum? What would it mean to teachers and students to take a more adventurous view of the subject? What kinds of teaching strategies would teachers use with nontraditional ways of treating content? How would they justify these strategies to parents and students? What effects would these less "reliable" strategies have on class control? On motivation? On evaluation and grade progression?

The Senior Years

Derrick, Prairie, Lavoisier and Red Cliff — the four cases that constitute the study of science education in the senior years — illustrate a number of dilemmas facing teachers of the separate sciences. Central to their work is a tension between "covering" the required and considerable subject matter so as to lay the foundation for future work, and promoting student interest in that work through an inquiry method that takes time, that can be difficult to evaluate and that is problematic in its own right. While the subject matter to be covered is specified by official documents and by texts — and these are followed closely — the ways in which this content can be made interesting and relevant to students is a matter of some uncertainty for the teachers of the senior grades.

These teachers view science as a method of precision characterized by exact numbers and highly organized bodies of information with specialized terminology. Accordingly, they are concerned about providing students with the notes and the practice with problems that are essential for success on examinations stressing recall of facts and the solving of numerical problems. The teachers say that approaching science teaching this way is both satisfying to them and necessary for their students: the task is relatively well-defined and the resulting student activity enables the students to perform well on tests, learn desirable habits and prepare for more of the same kind of activity in later grades and university.

Where they occur, alternative approaches such as stressing inquiry processes, relating science to social issues or relating science and technology are seen not as central activities for the science classroom but as a means of encouraging students' interest. Teachers say they are leery of allowing these approaches to form the core of their work, partly because the activities are not stressed in the documents they use to guide their work and partly because the teachers are not sure how to base their classroom activities on such approaches. The views teachers hold about alternative approaches to science teaching appear to flow from their conception of the nature of science itself.

Teachers' approaches to laboratory work reveal most clearly the way they think about the nature of their subject. Almost without exception, work in the lab is viewed as illustrating facts and theories presented in the classroom. What happens in the labs also confirms what is discussed in class. At Derrick High, for example, one teacher stressed the results that students should get in order to have performed the lab correctly; another stressed the importance of scientific notation; another, that students were to store a library of precise facts in their "computers" (their minds). Obtaining precise facts was what students did in their laboratory work. The same view was expressed by a teacher at Red Cliff High, who stressed the importance of precision in measurement and of finding the right answer. Indeed, measurement is the basis for students' science work.

For a teacher of physics at Red Cliff, the labs are supposed to reinforce the theory of the course; getting the right answer to problems is what matters. Working towards "the anticipated result" is seen to be the important thing. In biology, neatness is stressed and students are encouraged to be "diligent." At Lavoisier, the lab work is intended to make the ideas of the lessons "concrete"; students were seen to follow precise written procedures, but apparently without understanding the point of the lab and what might be concluded from it.

Allied to the search for "right" answers in the lab is the work students do on problems in physics and chemistry. The way teachers view this "problem-solving" activity also indicates how they view the nature of science. At Derrick High, chemistry students spend considerable time working out problems in order to apply principles and get correct answers. At Prairie High, the physics teacher valued quantitative problem solving because it prepared students to be systematic in their own lives. Similarly, at Red Cliff High, the physics teacher had hopes that students would see the "logic" behind the problems they solved, but she was not convinced that they did. Doing problems, she felt, contributed to skill in organizing one's thinking, in being disciplined. At Lavoisier, students regularly did questions from the end of the chapter, and by doing so they appeared to concentrate on the "knack" of solving problems rather than on understanding their meaning.

One can detect in the comments of many teachers in the senior-years schools a concern about whether students understand what they are doing in science class and whether, by adopting alternative approaches, teachers could improve their understanding. However, in spite of an awareness of what might be gained by adopting alternative approaches, most teachers considered such approaches impractical, except as isolated events designed to interest their students in the lectures and labs. Alternative approaches were not seen as bases for exploration into the nature of science and the relations between science and society, nor as a way of lending meaning to the work the students did day by day, period by period.

Physical science, for example, is presented as a body of knowledge based on careful, precise observation whose conclusions are justified by that precision. Science is seen as yielding mathematical formulations that can be used to process data in order to obtain precise numbers that describe the physical world. Biological science is seen as less precise, but still yielding organized knowledge in the form of taxonomies and terminology.

When teachers were asked how students benefit from such an approach to science, socialization goals predominated among their answers. Achieving high marks and moving forward through the school system to university were given as important reasons for learning the material presented. Allied to this emphasis on grades and credentials were teachers' claims that doing the labs and procedures developed in students habits of diligence, self-reliance, systematic inquiry, objectivity, industriousness, orderliness and tidiness. What was absent in the remarks of these teachers was a view of science as a basis for developing intellectual and moral capacity.

With the stress that teachers place on learning science as a body of right answers and on the "social" dimensions of such learning come a number of problems that confront teachers in their day-to-day teaching. Some of these problems are perceived by teachers to stem from the way they teach, some arise from the character of the students they teach and others emerge from the system in which the teachers find themselves. Stress on the conclusions of science and the emphasis on "socialization" may enable teachers to resolve some of their problems; but at the same time this stress creates other problems.

Consider the matter of students' abilities, interests and needs. Teachers believe that many students find it difficult to infer relationships and explore the implications of theories on their own. They believe that students need to be encouraged to learn. They believe that parents want teachers to ensure the "success" of their students. They believe that students need teachers to "boil" down the material with which they are confronted. They believe that students enjoy seeing a definite "end product" to their work. They also believe that universities must be satisfied with what teachers do. They believe they are not competent to lead discussions about "subjective" issues. They believe that students want "grades" as success tokens. They also believe that students are easily distracted, that they want "push-button" answers and that they cannot read or do mathematics. These beliefs provide us with some insight into how teachers construe the nature of their job, and these beliefs are central to understanding what happens in classrooms and why it happens.

Given these beliefs, we might see the stress on socialization matters as a natural response. Students are encouraged to learn in order to do well on examinations and achieve good grades. What they have to do to achieve good grades and credentials is clearly laid out, and they are rehearsed in the procedures they will need. For the students, the teacher is a necessary and reliable guide providing a "carrot" to help them organize their work and overcome their "laziness" and their inability to handle abstract relationships. The restricted subject matter provides a clear indication of the work to be done; the work is well-defined and the relationships among the work, the student and the teacher are relatively clear. Optional material, where it is suggested, can be safely ignored because it is not part of the work towards examinations and does not enter into agreements, made between teacher and students, concerning success on examinations. Teachers can avoid the risky business of treating "subjective" issues, about which they often feel incompetent. In showing how problems can be solved and lab work correctly interpreted, they are at their most competent; by their own admission, they are at their least competent when dealing with more open-ended, value-laden matters. Dealing with "cut-and-dried" matters is safer and more functional, given the way teachers construe their working conditions and what is expected of them.

The teachers stressed the importance of achieving positive relationships with their students. How, they ask, can such relationships be established? Most clearly, by ensuring that students are "successful," but also by stimulating their interest. Here the teachers expressed concern about the interest students had in their science work and the need to do "interesting things." Optional work, however, while "interesting," was considered to be peripheral. At Prairie, more so than at the other schools, the teachers spoke highly of such work, but for these teachers a dilemma clearly exists: the interesting work is not essential and time presses them to cover the less interesting but "real" work. Moreover, the optional work is often difficult to teach, so it is not surprising that such work finds little room in the activities of the classroom itself.

Yet a more serious dilemma persists. Beyond the matter of interest, perhaps the most significant question emerging from these cases is, "Do the students understand what they are doing?" It seems that students may not always understand the context that gives meaning to the lab and problem work they do. At Derrick, for example, in spite of the stress on accuracy, large errors in experimental findings were not discussed; the "right" answer itself was stressed. Dissections were rushed and reports of the work not made. At Prairie, teachers complained of students not writing their observations in their lab reports. Similarly, at Lavoisier, students could not draw conclusions from the lab; they did not appear to know what the point of the lab was. Teachers there said there wasn't enough time to look at the implications of the work done in the lab. At Red Cliff High, an important part of an experiment was not done, and a key concept could not be discussed in relation to the data. In biology at Red Cliff, dissections were done, but the students were not asked to organize their findings.

The teachers are aware of the problem of student understanding, and they recognize that an "inquiry" approach might promote better understanding. Nevertheless, in the main, they reject such an approach. They cited various reasons for this attitude. At Derrick, one teacher said he had not considered alternative approaches because the daily routine did not allow for such reflection. At Prairie High, a teacher said that that type of work doesn't "sink in." Another teacher could not see the "academic" value of looking at science-society issues, and yet another said that "nature of science" topics took time away from the content of the discipline: it wasn't an efficient approach. One teacher at Red Cliff High said that "discovery" was really a "carefully programmed exposure to ideas."

These teachers *are* concerned about what sense their students make of the science experiments and about the potential of alternative approaches to contribute to students' understanding. Yet for a variety of reasons important to teachers, they have not reflected very much about how they might use these approaches more centrally in their work. Other goals, which are mostly unrelated to alternative strategies, absorb their time and attention.

Because they hold that there isn't enough time to do the optional work, many teachers view that work as a "digression." But if there were more time, would these "digressions" be viewed as any less peripheral? Does the low status given to optional work not reflect, rather, these teachers' beliefs about what their central tasks are and how they can best be accomplished? Given the beliefs these teachers have about their work, it is not surprising to find them teaching science as a body of right answers. Some outsiders might take a sceptical view of such an approach to science teaching. However, we must consider the beliefs of these teachers in the larger context of students', parents' and the school-systems' definitions of "success" in the culture, the way schools are themselves organized, the nature of teachers' undergraduate education in the sciences, and the efficiency of teacher education programs in promoting alternative and richer conceptions of science education. These factors loom large in any attempt to think about how science education in Canada might evolve. It is to these matters that we turn in our concluding comments.

Major Issues: A Basis for Deliberation

The overall purpose of these case studies is to better understand how teachers approach the task of teaching science in the different divisions of the school. Issues that, in our view, are important to teachers and to a discussion of the present state of science teaching are organized below under these headings: integration and options, socialization, the inquiry approach and understanding, and change.

Integration and Options as Forms of Curriculum Organization

What appears to be the main concern of the early-years teacher — following student interests — becomes for the senior-years teacher a constant frustration. For the latter, the more "interesting" work that could be done cannot be done because there isn't time for it; the core has to be covered. Senior-years teachers teach science all the time and are able to develop a repertoire of proven routines, whereas in the early years, teachers teach many subjects. Whereas the senior-years teachers worry about which science topics to include or exclude, the early-years teachers may find it difficult to include any "science" at all. By adopting a rhetoric of integration it is possible for curriculum policy documents to discuss "science" in the early years without saying what the science topics should be or how they should be related to the science work that comes later. So, while early-years teachers may be able to follow the interests of students, they are also somewhat free to follow their own interests, and this freedom may lead to little science or a great deal of science being included in their teaching. Is this approach an adequate basis for establishing how science should function in the early years of a child's schooling?

Middle-years and senior-years teachers are faced with the problem of how to deal with core requirements and options. As science is seen as a minor part of the early-years curriculum, so options appear to be a minor part of the curriculum in the later years. A rhetoric of options enables official documents to acknowledge nontraditional topics and approaches, yet in practice options are often ignored under pressure of time. We must treat teachers' reference to time carefully because it appears to be an acceptable way of expressing preferences without saying they are preferences; teachers cite "lack of time" rather than "preference" as the reason why certain potentially desirable things are not done. If it is the case that options are not exercised by teachers, then how appropriate is the prevailing "core-plus-options" approach to curriculum policy making?

Socialization as a Priority

What of teachers' emphases on right answers, correct procedures, routine and the "facts" of science? In the middle and senior years, in the core areas of curricula, teachers view the subject of science as a body of right answers. They approach science with their students, not through disciplined curiosity, but through correct procedures and precise calculations. It is difficult to characterize early-years teachers' views of science, given the limited information we have and the enormous potential for diversity in approaches to science teaching at this level. Because the rhetoric of integration employed by some teachers stresses general intellectual skills such as problem solving, we might say that teachers think of science as "probing the curious." (Contrast this view with the "precision" view of science held by teachers in the later years.)

The "precision" view – one that stresses right answers, terminology, exact numbers, careful notes and doing "problems" – springs from an overriding concern of teachers to inculcate good habits. This emphasis in teaching is often termed *socialization*. Social priorities are stressed: good work habits, diligence, preparation for future work, attentiveness, being prepared and following instructions. What is not stressed are the intellectual functions, especially critical thinking and good judgement. We do not wish to minimize the values inherent in the socialization view of science teaching; there are good arguments to be made for it. But we do question whether this social rather than intellectual emphasis is a desirable one for science education. Given the complex role of science in our cultural and political lives, is socialization a wise priority?

The Inquiry Approach and Understanding

We find that the emphasis schools place on diligence enables teachers to make use of apparently reliable and secure approaches to teaching. An inquiry approach to science teaching is viewed with suspicion by the teachers in many of these cases. The existence of this alternative approach is a constant reminder that other possibilities for science teaching do exist, possibilities that can only be realized by taking a different view of the subject and by struggling to achieve a new balance of emphases in one's teaching. Alternative approaches to teaching can remind teachers that, in an ideal world, they might prefer to use an approach that emphasizes both social and intellectual development.

As many of the middle- and senior-years teachers see it, to study science through inquiry (that is, to engage students in discussions about what is and what ought to be the case) is, to put it bluntly, to work in an inefficient way. How can the extensive subject matter that is mandated be covered? How can valid and reliable tests be set when inquiry is the approach to teaching? Prevailing answers to these questions have not satisfied these teachers.

When inquiry-based emphases are suggested – in optional sections of science curriculum documents – they tend to be ignored, or used sparingly as ways of "motivating" the students. Nevertheless, middle- and senior-years teachers are concerned about the way they usually teach science. They are worried about students' interest in their lessons, which emphasize the transmission of facts: are students motivated by such lessons and, further, do they understand the facts in relation to the methods and theories of science? Without the context provided by the methods and theories of science, and without an understanding of the social implications of the technology based on those theories, the isolated facts and laws of science remain in danger of being seen by students as pieces in a never-finished jigsaw puzzle. Here lies an unresolved problem for these teachers and a significant topic for deliberation.

Dynamics of Change and Dilemmas of Practice

Not all these teachers are trained scientists and not all work with ample resources, but all of them do work with large numbers of children whose abilities vary considerably and whose home support varies even more. Teaching children with such a range of social and psychological backgrounds is very demanding. Add to this difficulty the lack of any clear consensus about what schools are for and the result is a task that is ambiguous and poorly delineated. We believe that teachers actively counter these forces, which place unlimited demands on them, by interpreting and carrying out their jobs in a particular way. Given the uncertainties that exist about subject-matter competence, students' behaviour and educational goals, it is not surprising to us that teachers approach their work in ways that make it less uncertain. If we accept this view, it is also not surprising that certain apparently limited views of the subject and its educational functions prevail at all levels of science education. We believe that teachers react to the many problems confronting them by promoting those objectives and using those methods of instruction that make their jobs less ambiguous and less threatening. To ask teachers to change their methods and objectives without first considering the reasons they behave as they do in the first place is unwise, to put it mildly.

Having said this, we are not urging that the existing situation be enshrined because the educational system is difficult to change. Sources for productive debate and improved practices lie with the teachers themselves. They are aware of the dilemmas inherent in their work. They know that trade-offs are being made constantly, and it is clear that many of them are less than happy about these trade-offs. The dilemmas are many:

- How can teachers develop good work habits in students and maintain their interest in science?
- How can teachers include science topics in the early years when society demands the teaching of "basics"?
- How can teachers stimulate thought, especially by means of optional material, and still cover the core material specified by authorities?
- How can teachers control students' energies without suppressing imagination?
- How can teachers portray fairly the nature of science and yet enable students with different abilities to understand the basic concepts?
- How can teachers reconcile the apparent objectivity of science with the apparent subjectivity of value-laden issues related to science?
- How can teachers cover the work yet ensure that students understand it?
- How can teachers meet the expectations of parents and students for grades and credentials while at the same time pursuing sidelines that are not directly related to testing and examination?

These are the principal dilemmas we see inherent in what teachers have said in these case studies. How teachers and others view the trade-offs science teachers have to make, and how they view the consequences of these trade-offs for realizing the full potential of science in the school curriculum, are matters for further study and deliberation.

II. Teaching Science at Seaward Elementary School

Mary M. Schoeneberger

The Setting

The Community

Seaward is a quaint seaside village that lies nestled among the inlets and coves of a scenic Maritime coastline. In this rural community of about 1500 residents, a pulp and paper mill and its associated lumbering activities provide much of the employment for the people both in the village and in the surrounding countryside. Some small-scale industries also operate in the area, including hydraulics, custom machinery and small cottage industries; most other people work for "small outfits," or are self-employed as merchants and craftspeople. Fishing provides work for some residents. Most of the fishermen operate off large company trawlers, although in some inlets, away from the town, a few fishermen continue to run their own boats and attempt to preserve a way of life that is rapidly disappearing. Unemployment in the area is high. During the summer months, the area is a favourite spot for tourists, who come to enjoy sailing and swimming, to browse in craft shops and to enjoy home cooking and seafood which is available along the waterfront.

Seaward and vicinity is a long-established, stable community, many of whose permanent residents were born in the area. Generations of families, largely of Anglo-Saxon descent, continue to live and work here, with some family groupings choosing to live close together in clusters, as the mailboxes along the roadside indicate. The school principal estimates that, if five or six family names were removed from the class lists in the elementary school, "it might take care of 30 per cent of the school's population."

According to several teachers at the school, the concerns of people in the area tend to centre around events close to home, particularly events which affect them directly. Residents do not appear to be very aware of or interested in what is happening elsewhere in the world, how it affects them, or "where they fit into the broader scheme of things on a national scale or even an international scale."

Change, in general, tends to be resisted, especially if it might affect someone personally. Sometimes, however, the community opposes things which, according to the principal, "need to be resisted," and parents have been known "to get up in arms" in support of an issue that they consider important. Such was the case a few years ago in regard to the need for improving special services for the elementary students. In that instance, the community had perceived a need for a reading specialist and kept "pushing" until, when an extra teaching position was allocated to the school for the teaching of art, community pressure influenced the decision to hire a reading specialist instead.

While reading is of concern to the community, science is not. The general consensus at the school is that science appears to be a "non-issue." Neither the principal nor the teachers can ever recall any parent asking about or even mentioning the school science program. On the rare occasion when science has been brought up during parent-teacher conferences, it has been in relation to a child's mark or perhaps a question about a textbook. The principal cannot recall science ever being mentioned or discussed in the course of his dealings with school trustees, school boards and home-school associations over the years; the same was true, however, of subjects such as health, social studies and art. The primary concern seems to be for the "basics." One teacher, who has been in the school system 16 years, described community concern for science this way:

> "I'm quite certain that you could go a year without teaching science and there would be no comment. Parents see it as a little added frill, maybe. I don't think they see it being as important, for instance, as math is — that you know how to add, subtract, or that you are able to read. And perhaps another reason [why parents do not consider science important] is the way high school programs have been over the years; you choose to take science if you so desire. Most people didn't take science courses unless they were going into medicine or nursing or somewhere they had to have it; otherwise they bypassed those courses."

The School

The present Seaward Elementary School is in its second year of operation. According to one long-time teacher, it took nearly 20 years of talk, discussions, planning and promises for the new school to become a reality. The school is situated on the top of a hill which, to the rear, gradually descends towards the ocean several hundred metres beyond. Off to the side of the school and behind the playing fields is a wooded area that provides one of several ecological areas for the school.

Most of the classrooms are self-contained, with the exception of a kindergarten-grade 1 combination, a grade 5-6 combination, and two grade 7s, which occupy the three open-area spaces within the school. Although each of these classes has its own space, teachers sometimes team-teach or teach a specific subject to both grades. For example, in the grade 5-6 area, one teacher teaches all of the science while the other teaches all of the social studies. Children are heterogeneously assigned to all classes, with the exception of the special education classes.

The school has classes from kindergarten through grade 7. Almost 400 students are enrolled, and about 100 of these are in grade 7. About 60 per cent of the students are bused to school, while the remainder live within walking distance. Most of the elementary students live within 12 miles of the school, although some of the grade 7s live much farther away.

The grade 7 classrooms are located in a wing of the school away from the other classrooms. Because this group begins school 35 minutes later than the rest of the student body, their timetable also contributes to keeping them physically separated from the younger students. On certain occasions, such as assemblies and school plays, the entire school does participate as a unit.

The school is staffed by a principal, 14 classroom teachers (three of whom teach grade 7), and seven specialist teachers for special education, reading, music, French and physical education. All but three of the teachers are women. A support staff of seven provides library assistance, secretarial help, a school lunch program and general maintenance of the building, while volunteers assist in the library, on field trips, in administering speech therapy, and in teaching special education and reading.

The Curriculum

Language arts and mathematics are the primary concern not only of the community at large, but also of the provincial Department of Education, the school and the teachers. Provincial guidelines allocate instructional time in the following way:

In grades 1, 2 and 3:

language arts
(incorporating social studies) . . . . 55 per cent

mathematics education	15 per cent
science education	10 per cent
physical and health education	10 per cent
music education and art education	10 per cent

In grades 4, 5 and 6:

language arts (including French)	40 per cent
mathematics education	20 per cent
science education	10 per cent
social studies	10 per cent
physical and health education	10 per cent
music education and art education	10 per cent

Accordingly, the school handbook informs parents that the major emphasis of the program at the elementary level is "on the development of communication skills — reading, writing, listening and speaking." The second major area of emphasis is on mathematics, but science, social studies, music, art and physical education are also included in the program. French language, which is taught in grades 3 to 7, is considered part of language arts.

The teachers also consider language arts and mathematics as the most important areas of the curriculum. One teacher summed it up this way: "Well, your reading and maths are always your priorities and everything else, health, science, social studies, is lumped into what's left over."

Depending on how calculations are made in the six-day teaching cycle, the 10 per cent time allotment for science averages out to approximately 120 minutes every six days for kindergarten through grade 2, and 150 minutes for grades 3 to 6. Of the 10 classes in which science teaching is supposed to occur regularly, only two receive science instruction for the officially allotted time. Most classes receive considerably less science instruction and some receive little or none at all, at least on a regular basis or in a form which could be identified primarily as "science." The reasons for this situation appear to be many and varied.

Teaching Science

The Program

Provincial guidelines for teaching elementary science provide the general framework for what is taught in science at Seaward. *STEM Science* (Addison-Wesley, 1977) is the primary resource available for teachers and students; one set of textbooks is provided for students at each grade level. Some teachers follow the textbook quite closely, while others are selective, preferring to use *STEM* as a supplementary resource, as a guide, or not at all.

There is no overall coordinated school plan for the teaching of science, although sometimes several teachers might cooperate in planning a program for several grades. This year, for example, the grade 5 and 6 teachers attempted to coordinate their programs by deciding which topics would be taught at each grade level, in order to avoid duplication and also to ensure that a variety of topics would be included. It was anticipated that this approach would "cut down on planning time" and allow teachers "to do something in depth." Initially, teachers selected individual topics according to their interests and strengths and agreed to gather the necessary materials, which would be shared. To facilitate this agreement, grade 5 and 6 textbooks were to be ferried back and forth between classrooms as the need arose. The teachers felt that this arrangement would provide students entering grade 7 with similar science experiences during their last two years of elementary school. Several months into the school year, however, it became evident that this system was not working as intended. The "kits" never materialized, and the teachers gradually reverted back to teaching individual programs. One teacher suggested that lack of communication was a major reason for the demise of the plan.

Equipment

According to one experienced teacher, during the last six years equipment for science teaching has been much more readily available than before. During this time, several systems for organizing equipment were tried. About five years ago, a group of teachers in the district who were "keen on science" decided to make up kits which would be available for use by all teachers. Mr. Blake, a grade 5 teacher, took responsibility for coordinating the development of the kits at Seaward School, using funds provided by the school board and the local chapter of the teachers' union. According to Mr. Blake, the outcome of their effort meant that "if you were working on magnets, for instance, you had iron filings, magnets and a compass. Everything was there in the box, and if you were working on that topic, you just took the box and you had everything you needed."

For several years a number of teachers, particularly those in the intermediate grades, made good use of the kits, but, because there was no system for circulating and maintaining the kits, pieces of equipment gradually disappeared and the kits fell into disuse. There is still no system for organizing science equipment in the school, nor is the equipment stored in one central location. This lack of organization is a source of frustration for some teachers and is perceived as a barrier to teaching science.

When the new school was completed, a capital grant was included in the budget for science equipment, with the result that an assortment of equipment was purchased for the school, including a class set of elementary microscopes, test tubes and racks, bells and so forth. Much of this equipment, which is stored near the principal's office in the original packing case, does not appear to be widely used, perhaps because it is largely inappropriate for the *STEM* program. Equipment that would be appropriate for the program — such as styrofoam cups, paper plates, string, nails, etc. — are commonly found in supermarkets and hardware stores, for which reason they cannot be purchased with funds from the existing capital grant.

At present, ordering of school equipment of all sorts is done centrally; each teacher submits individual requests and these are examined in terms of priorities and available funds. Under this system, there is no guarantee that all requests can be filled. Some teachers say their previous science requests have not been funded, so they do not bother to ask any more; others seem satisfied. The system does require teachers to do long-range planning, because orders are placed each spring for the following school year. Many teachers miss the deadline. Teachers who do not have the necessary science equipment either purchase it themselves and are reimbursed, or pay for it out of their pockets, or do without. Whatever the case, it often means that there is not enough equipment to actively engage all students in doing science. One teacher explained how she organized her classes around the equipment that was available for a unit on electricity:

> "I had a large class of grade 3s and 4s and I taught *STEM* in both grades. The electricity unit was particularly a hands-on unit — more so than the other ones. We did experiments. . . sometimes I had two or three children perform the experiment; sometimes I performed it. Sometimes it was set up so that there were perhaps four or five groups doing different experiments from the same unit and then pooling the information gained. We never had enough materials for the whole class to be working on the same experiment, because I was looking after 35 students and I didn't have 35 of anything. So, in the end, there were a lot of demonstrations. Occasionally, each child had something to work with, as when each child brought a wire, a bulb or a battery from home. In other cases, we pooled the resources. It was set out so that not everyone did the same experiment each day. One group of kids was responsible for the experiment on one day and, on another science day, another group would be involved while everyone else watched. And, we wrote up experiments in a fairly scientific way in terms of equipment, method, procedure, observation and that sort of thing."

Lack of Confidence

Many of the teachers say they feel less comfortable teaching science than they do most other subjects. This feeling, which often appears to reflect a general lack of confidence in relation to science teaching, seems to be associated with several factors. According to the teachers, these factors generally include a weak background in science, unfamiliarity with the science program at a specific grade level and the lack of structure provided by the ministry's guidelines and other curriculum aids. One teacher, who is in her second year of teaching at the grade 6 level and who typifies this predicament, explains it this way:

> "Oh yes! [I do lack confidence], especially not having the background knowledge of science or knowing exactly what is in here [material for a unit on the solar system] or what the students are required to learn. Or this unit on electricity and magnetism — what exactly is in here? How far does it go? Things like that I didn't really know, and it was almost like keeping myself one step ahead of the students during the first year. Now at least I feel I have that knowledge and I can develop it a bit further and, hopefully, see it the way I want it to work.
>
> "Last year, I was really lacking in confidence. What the course last summer [a one-week science workshop] gave me was a bit more confidence to try these things on my own. You know, no matter if they [the experiments at the workshop] were a huge flop, at least you tried them. Before, I had the idea, 'Well, if I do this experiment as a demonstration and it turns out to be disastrous, then how will I explain it?' What I learned from the course was that there is no right answer. . . it's not all black and white. It's a process, and I guess that's it in itself — just having fun; and also learning from what you do. I feel better about what I am doing in science this year than I did last year. I'm approaching it differently."

The principal, who is aware of teacher concerns about science, suggested that some of them feel less comfortable with science because the curriculum is not as prescriptive as it is in some of the other subjects:

> "I think teachers generally feel less comfortable with science and social studies than they do with the rest of the subjects. Even if you take, for instance, a teacher who went to university and got a BA in history and English, and fell into education and ended up in a school — they generally feel reasonably comfortable with the language arts program because the reading text is fairly prescriptive in nature and so on and so forth. In a lot of cases, you see, there's a framework on which they can hang their program and get through. Science and social studies haven't been in the same kind of situation. . . Science is better off since the new curriculum guidelines [came out four years ago], and also since, in this school, we adopted the *STEM* program and provided the materials for *STEM*, too, but nevertheless, it's the curriculum area that most teachers, if they're

> BA people or if they are nondegreed people, feel very uncomfortable with. . . . It's something they *can* do – you don't need to be an Einstein to carry off the science – but they are uncomfortable about it and, therefore, reluctant to get into it."

Scheduling Science and the Lack of Time

The normal school day includes 275 minutes of in-school time, with classes scheduled over a six-day cycle according to the percentages recommended by the provincial guidelines. In practice, however, there is no standard formula for determining actual teaching time for in-class subjects; thus, broad discrepancies in allotted teaching time for a specific subject can and do exist. For example, one teacher at the intermediate level calculated 140 minutes for science in the six-day cycle, while another at the same grade level calculated 60 minutes for the same time period.

Although teacher-made timetables may show that 10 per cent of the time has been allocated to science, it does not necessarily follow that all of that time is actually devoted to science teaching. In some classrooms the timetable is followed regularly, but in others it is not. "Sometimes I just don't have time to get everything in" is a common statement. On other occasions, science time may be used as a make-up period for other subjects.

One teacher at the intermediate level who is teaching a new grade level this year felt that during the first few months she had to spend most of the time becoming familiar with the language arts and mathematics programs. Until she had those subjects "under control" she did not have much time for other subjects, including science. During this adjustment time, her class did do some work on the topic of water and land but, as she said:

> "They've just been reading and talking a lot, mainly discussion. I hate to have them just reading a book. Actually we haven't even filled all the science periods. We were just talking about a lot of general things. . . . As far as experiments go, I am not really experiment-oriented, although I enjoy doing them. Part of it is I really don't have the materials. I'll have to see what I can do about that."

Those subjects that are taught by specialist teachers (music, French and physical education) are prescheduled and therefore are always taught on a regular basis.

Lack of sufficient time in which to teach science is also a common complaint of teachers. They note that new subjects are continually being added to the curriculum, but seldom are any removed. The school's change from a five-day to a six-day teaching cycle helped to alleviate this situation. However, even with this arrangement many teachers continue to find it difficult to teach everything that is required in the time allotted. Consequently, they say, some subjects "suffer"; science is often among them. Language arts and mathematics nearly always receive attention as prescribed, and in some classrooms these subjects seem to dominate the program.

Integrating Science

Some teachers justify the limited time spent on science per se because they feel that they "integrate" science with other subjects, and thus, they say, more time is actually spent on science than might appear on the timetable. Because integration is a common practice in elementary teaching, it is perhaps not unusual for teachers to believe that the "science" they teach in this way is an effective way to approach the subject. Upon examination, however, most integration appears to mean primarily talking about topics which might be science-related rather than "doing" science. A grade 1 teacher gave the following example of how she integrates science in her classroom:

> "I tie it in with the reading course. For example, *Surprise, Surprise,* which is the first reader in the series, starts off working with pets, the pet shop, going to buy a pet; so, instead of going from the *STEM* book on animal needs, I build from the reading course – like I integrate it. So, we start off with, for instance, the types of animals that you would have for a pet – tame animals and what they need – and then we go to wild animals and what their needs are. Really they are getting it from discussion; they are getting it from their own home experience at that stage. About the only thing we did was that the children each brought in a picture of their dog, told us about it, wrote a story about their own dog, and then the photograph went on a piece of paper with the story."

These approaches suggest that science is primarily conceived as a body of knowledge that can be imparted through a variety of means and that does not have to be formally labelled as "science" or presented during a special time of day devoted primarily to "science." Only one teacher was observed to integrate science regularly by beginning with organized science activities and then extending the learning to applications of science in mathematics and language arts. In addition, this teacher emphasized ideas and information that were related to science throughout his program. According to the principal, there are times when integration presents the opportunity to "hide science or social studies in one another." Integration could also be a way of rationalizing the fact that not enough science teaching is actually occurring.

Science Experts

Two teachers (in the kindergarten to grade 6 range) are perceived by the staff to be particularly interested in science. Although one of them is considered to be "quite a science expert," both of them are thought to "know a lot about science" and to "like to teach it." Both are men, and both have science programs that are always taught regularly. The remainder of the staff do not consider themselves particularly competent in science and certainly not "science experts." According to the principal, this situation is typical of most elementary schools:

> "You probably noticed yourself the limited hands-on things that are going on in science and so on, and I think it's fair to say of students that during their career in elementary school — and this is not just true here; it's true in most schools — if their luck is average, they are going to hit one teacher at least, maybe two, who are keen on the science aspect of curriculum, and probably you are going to see some of the social studies dragging its heels if the teacher is concentrating on science. I don't feel badly about that because I think it probably evens out on the social studies side with another teacher."

Science Background

It should be recognized that most of the teachers at Seaward have taken several reading and language arts courses during their preservice teacher education programs. Also, most have since taken additional language arts courses at both the undergraduate and graduate levels, and many have attended the reading and language arts inservice courses and workshops regularly available throughout the province. This training has helped them feel more competent and comfortable in teaching language arts. Such is not the case with science. Only one teacher at Seaward has studied science at the university level. Several others studied some science in high school (typically biology and, perhaps, chemistry), while a few took no science at all. Several teacher's college graduates studied science in one course during training, but none of them considers these courses to have been of much value, particularly because they took place "so long ago."

In the two institutions within the province that train the majority of elementary school teachers, science methods courses are not always available, let alone required. At one of the institutions, as recently as five years ago, a science methods course was offered only to those students preparing to teach at the intermediate level. As some of the teachers currently at Seaward concentrated in early childhood education, they did not take the course. One teacher, who is now assigned to the intermediate grades, regrets not having had a science methods course. At the other institution, a six-hour noncredit workshop in science methods has been offered to all prospective teachers in the past few years. Plans are now being made to introduce a science course. The fact remains, however, that graduates of that program have few or no science teaching methods to call upon when they are teaching science.

Inservice Education in Science
Due to their lack of preservice preparation in science and science methods, Seaward teachers must rely on inservice and continuing education courses to improve their background in science. However, opportunities for upgrading, particularly in science content, appear to be limited or nonexistent.

Science inservice activities for elementary teachers at the district level have been rare; the few that have been available were usually one-hour or two-hour sessions offered during meetings of the teachers' association. However, because all associations (covering the various subjects) hold their meetings on the same day, teachers must make choices, and only a few have ever chosen science. The principal explains this fact by suggesting that teachers feel uncomfortable with science and prefer to attend workshops in "safer" areas. Also, the emphasis the school places on language arts and mathematics probably increases attendance at those workshops. Teachers who have attended the occasional science workshops, however, have often been disappointed with their quality. As one teacher said:

> "I have attended a lot of inservices in reading and creative writing — things like that — and I could still go to a lot more, but with science, I have never really attended any great workshops. You know the conferences we have every year; I have never attended anything that has helped me in the classroom."

In the past six years, only two inservice days were devoted to science, and at only one of those was attendance by teachers required. Most of the teachers at the school said they would be interested in attending some science workshops, particularly if they were designed to meet the needs of their classrooms.

One type of inservice education that has been attempted on a provincial basis involves inviting one representative from a school district to a one-week intensive workshop, with the expectation that participants would convey what they had learned to colleagues in their home districts. The assumptions here are that knowledge and experience gained at the original workshop will eventually become widely disseminated, and that teachers attending the workshop will be equipped to do "teacher training."

Several years ago, Mr. Blake, a grade 5 teacher from Seaward, was selected to attend a one-week intensive workshop on the *STEM* science program, an experience he reported as having been well received by all participants. He returned to Seaward to conduct a workshop for teachers in the district but was not satisfied with the outcome. Mr. Blake felt his presentation had been too theoretical, and he was not sure what the teachers had gained from the experience. Although some teachers did say they found the session interesting and informative, their actual teaching of science did not seem to be affected. The principal, who had participated in a similar inservice activity for mathematics teachers ("following which I didn't disseminate what I had learned at all"), finds this type of inservice education to be a generally ineffective way of improving science teaching:

> "It is fine in theory to say, 'Well, this is how we will disseminate here because we will spend some dollars and we will get these key people and then they will go back and spread the gospel, and so on.' In my experience, it doesn't work that way. It makes a big difference to the person who attended [the workshop], but that's probably where the difference ends. I just don't know. I think any kind of inservicing where we say, 'O.K., we're going to do a science inservice for the elementary teachers in this district, so we're going to gather 65 of you together and jam science down your throats for an hour,' isn't effective because, first of all, it is very difficult to get teachers to an inservice on time and get the inservice started on time. It's very difficult to restrict a coffee break or a mid-morning break or lunch at noon and have everybody back at 1:30 p.m. The day ends up being so reduced by the social side of things. Not that that is all bad, because, I think, teachers need an opportunity to get together without other responsibilities so that they can socialize, because socialization has got school in the middle of it. You know they're talking about school things and science. Inservice isn't necessarily science, it's school things and, I think, there is a benefit to that which shouldn't be ignored. But, by the same token, if your objective is to disseminate something about science and, further from that, if your objective is that science programs in the classroom will improve because of that inservice, then that objective has had it!"

Leadership in Science

Leadership in science teaching at the district level has been limited. The district curriculum consultant, a person responsible for all curriculum areas, generally concentrates on the language arts and has provided little assistance in terms of science teaching to the teachers of Seaward. This situation is not uncommon. Most of the school-district consultants in the province who carry responsibilities for all curriculum areas in the elementary program generally have had little training in science. In fact, in a province with 21 school districts, there are only three school-district consultants with full-time or part-time responsibility for science. Thus the one provincial science consultant at the Department of Education faces the overwhelming task of providing expertise and assistance to teachers in the remainder of the province, in addition to the other duties required of someone holding that position.

Within the school, leadership in science has come to be identified with Mr. Blake, who has a strong background and burning interest in science, who is very active in teaching it and quite willing to promote it.

Over the years, Mr. Blake has been selected to represent the district at a special science workshop, has presented two science workshops to Seaward teachers (one mandatory and one optional) and others in the district, and generally has made himself available to colleagues for the purpose of providing assistance in the form of suggestions, materials, information and explanations about scientific phenomena.

Among his colleagues, Mr. Blake is recognized as the "science person" in the school. Mr. Blake suggests that he is perceived this way because he is trained in science and had worked in science-related areas prior to becoming a teacher. Most teachers, however, do not use Mr. Blake as a resource person on a regular basis although they know he is available if they wish to approach him. Because a classroom teacher serving as a resource person can only influence and be helpful but cannot demand, the onus for change remains with each individual teacher.

During the past several years, interest in and action towards developing the school science program at Seaward has peaked and waned. Those few teachers who have a personal interest in science and feel committed to improving it have continued to seek assistance and to work towards implementing a more activity-oriented science program in their classrooms. Most of the others appear to be carrying on primarily in a more traditional mode that is heavily teacher-centred and textbook-oriented, creating an environment in which worksheets are commonplace and hands-on activities are rare.

Teaching a Combination Kindergarten-Through-Grade-2 Class

The Classroom

Just outside Ms. Tanner's classroom, a brightly coloured rainbow with the word "WELCOME" printed below it greets everyone who passes by the room. One step inside suggests to children and visitors alike that this is a place for and about children. There is a hum of activity as children go about their tasks throughout the room. Evidence of children's creative work covers walls and countertops. A large yellow sunflower surrounded by poems covers one section of a wall, reminding children of their study of this plant, which flourishes in the area; several brightly coloured graphs created cooperatively by the class are displayed on other walls, along with poems and other bits of work produced by the children. Squiggly caterpillars, individually designed by each child, hang from the ceiling in another section of the room; a large calendar and weather chart, designed by Ms. Tanner and filled in by the children, records time and weather conditions from day to day, providing information for children to enter in their daily journals.

Books, both the commercially produced and homemade variety (made by the children themselves), are everywhere — on desks, countertops, carts, on the floor of the reading corner and on tables; several

"Big Books" sit on an easel for use by a group of children, although individual students often can be seen leafing through them. A pair of guinea pigs that live in a cardboard-box home (constructed by the children and situated on a counter in a "quiet" corner of the room) provide a constant source of observational material for students. The children learn to care for these small animals and, in Ms. Tanner's words, "it's so nice for the kids to have something to cuddle and play with."

A spirit of cooperative learning is encouraged by Ms. Tanner. Older children are encouraged to help the younger ones, although often the assistance is mutual. Ms. Tanner's desk, unobtrusively situated at one side of the room, is surrounded by shelves and books, while the students' desks are to one side near the front of the room in three clusters of eight desks each. Within the clusters, the desks are arranged in two rows of four desks, facing and adjacent to each other. This arrangement allows the children to interact freely with each other. Children from all three levels — kindergarten, grades 1 and 2 — constitute each grouping so that children can assist each other.

Another section of the room houses the reading corner, where the class frequently gathers throughout the day for stories and discussion. The coziness provided by the rug invites children to spend additional time in this area, reading quietly, completing manipulative mathematics assignments or doing a variety of other nonwritten activities.

Observing in this classroom was always a pleasant task for me. I was always warmly welcomed by everyone and made to feel a part of the class. Judging from the number of students from other classes who spent their recess, noon hour and after-school free time in Ms. Tanner's room, I was not the only one who felt this way. Because of the unstructured nature of the environment, I was able to move about freely and came to be accepted as part of the group. Usually, children were willing to enter into a conversation; often they came to request assistance, perhaps viewing me as another teacher.

Ms. Tanner

This is the first year for the "experiment" combining kindergarten and grades 1 and 2 in a single class. Although Ms. Tanner has been teaching for six years, it is her first year teaching kindergarten and grade 1. There are some "bright" students in the class, but a number of the children have experienced difficulty with reading and mathematics during their first years in school and are working below their grade level. Consequently, Ms. Tanner's primary objective is assisting students in mastering basic literacy and computational skills.

While Ms. Tanner feels that she is quite well-prepared to teach language arts and mathematics, she does not feel the same way about science. During her university studies, she did one year of introductory biology. In retrospect, she feels that her one science methods course was "a kind of hit-and-miss" experience, particularly "in relation to developing in students an understanding of the sequential development of process skills involved in doing science," an area in which she continues to feel somewhat inadequate.

Science in the Classroom Program

Ms. Tanner feels that, due to the nature of the children in her class, reading and mathematics must form the basis of the daily program, with other subjects, including science, flowing from these basic activities. However, because music and physical education are taught by specialists, these two subjects also appear regularly in the timetable.

Within this integrated approach, science is not taught as a separate subject. Although Ms. Tanner sometimes questions her reasons for doing this, she believes nevertheless that there are no clear distinctions among the different subjects and that integration is one way to give attention to all of them. She explains it this way:

> "I don't know whether it is a compromise or a cop-out on my part, but it seemed a comfortable way for me to handle the whole situation; it seemed to work in with the program. It seems that science is important, but it's not as important as getting kids to read and write and do math. Somehow [when students read, write or do arithmetic] they are not seen as doing science. Some people still seem to think science is science and reading is reading and math is math, and there is no dialogue or exchange between them, but I find just the opposite, that kids are interested. You know, if they are interested in whatever they are doing, they will learn to read or do their calculations or whatever is necessary in the context. They identify with reading and math quite naturally and quite easily, so that it facilitates the learning."

Another reason why science is not given specific attention in her program is that Ms. Tanner finds that she has no time to plan for it. During one of our discussions, she described the demands on her time this way:

> "I've found that I've just been so busy that I just haven't had time to project too far into the future which, I suppose, makes things even less directed than they might be. I find the three levels very demanding. I find at the end of the day I've just made it through, and I find it difficult to integrate planning into the teaching day. There are only so many hours in a day, so I find that a big problem and, I suppose, the newness of it all [is a factor, too]. Doing it all over again a second time would be smoother and easier. I do feel very rushed and pressured. I guess, in a way, if I was to follow a prescribed program [in science] that has been laid out, it might help, but I haven't really had time to look at the materials [*STEM*] and become familiar with them."

Ms. Tanner feels that one way of coping with the time problem is to integrate science with language arts and mathematics. Within this integration process, science is not planned; it "just happens." Ms. Tanner tells how this occurs:

> "Well, science just happens. There isn't a particular time on the schedule when it is taught. It happens in the context of the day, and it would be something that would be used to cultivate math skills, writing skills, reading skills — that sort of thing — so that the science would become an instrument for that, rather than just science for the sake of science. It would just overlap specific areas [reading, mathematics] which seem to be the major thrust. Reading and mathematics are most important, and the other subjects [science, art, etc.] serve those purposes."

Ms. Tanner's usual approach to topic selection is, as she says, to "go with the interests of the kids." The topics that she introduces normally emphasize skill development, such as observing and graphing. In the four-month period September to December, topics that related to science included apples, seasonal changes, sunflowers ("related to seasonal changes"), guinea pigs and dinosaurs. It was Ms. Tanner's idea to have the children take the temperature and note weather conditions; these are then recorded in their daily journals, an exercise which is also considered to be science.

Integration: Studying Dinosaurs

As a topic that evolved from the interests of the students, the study of dinosaurs serves to illustrate how Ms. Tanner integrates language arts and science. It all began with the reading of a book about dinosaurs. This event sparked a discussion that led to the students constructing dinosaur models out of plasticine. The rubbery creatures of many colours sat on a board just behind the more formal study area and were available for observation and admiration throughout the day. Some of the models could be readily identified as tyrannosaurus rex, triceratops and brontosaurus, among others. During the next library period, a few days later, the students took their models to the library where they were placed on display. The sign that accompanied the display read: "Please Be Gentle." At this time, many of the students asked to check out books on dinosaurs, and the four or five available books were quickly snatched up, leaving a number of children disappointed.

Over the next week, the children continued to request that books about dinosaurs be read to them. Several youngsters brought books from home and asked to have them read to the class. Ms. Tanner always agreed. In one instance, she challenged the class to see if they could "learn anything more about dinosaurs from this book." The children then heard about the environment in which dinosaurs lived, how they looked and what they ate. Most of the children seemed very interested in the story and listened attentively, but towards the end of the story and the discussion, two children — a boy and a girl — got up and returned to their desks. When Ms. Tanner asked that they return to the reading corner, both children reluctantly obliged, although the little girl muttered quietly, "I don't like dinosaurs."

Following the story and the discussion, Ms. Tanner asked the group if they would like to make a book about dinosaurs. Most children seemed to like the idea. Ms. Tanner told them that they could tell her the words and she would type them and then everyone could illustrate his or her ideas. This assignment set off a flurry of activity. Ms. Tanner rolled her typewriter out into the room, and as she sat down behind it the students crowded around her waiting for a turn. As each suggestion was given, it was typed and read out aloud.

"Some dinosaurs can eat other dinosaurs."
"Dinosaurs are very big."
"Some dinosaurs learn to fly."
"Dinosaurs come to school on the bus."
"Some dinosaurs eat water plants."
"Dinosaurs lived long ago."
"Some dinosaurs eat garbage."

Once the children had illustrated their ideas, their work was put together in a book that was read to the class and then added to the collection of books on the mobile book shelf. This book became a favourite of many children, who often could be seen leafing through it.

Emphasizing Process Skills
Throughout her teaching, Ms. Tanner says she emphasizes process skill development rather than content. She feels that it is more important to provide children with skills for "learning how to learn" than to concentrate on facts and information that probably will be forgotten. In particular, observation is stressed, as are graphing, measuring and classifying. Graphing began the first day of school when the class completed a graph that Ms. Tanner had prepared.

Where Did You Eat Your Lunch?

At Home	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
At School in Cafeteria	○ ○ ○ ○ ○ ○ ○ ○ ○
In Teachers' Room	○ ○

Each child selected a sticker and placed it on the graph in the appropriate row. Those children who were not able to read (most could not) received help from Ms. Tanner or another child. Graphs of this type are constructed regularly in this classroom and usually deal with topics the children have just experienced.

During one visit to the classroom, I observed a lesson in observation which was conducted around the introduction of two guinea pigs into the classroom. Ms. Tanner began by gathering the children in a circle on the floor. Everyone was asked to be very quiet so as not to frighten the newcomers. As the guinea pigs were placed in the centre of the circle, Ms. Tanner said, "I'm going to put these down on the carpet to run around the circle. If they come to you, just be very quiet and be very gentle with them. They will run around and visit you and we can have a good look at them. The white one is called Chris and the brown one is Mouse." The children sat quietly. One guinea pig moved near two children; the other guinea pig followed.

Ms. Tanner: What does it feel like?

Student: Soft. [The student touches the animal]. What are you playing, follow the leader?

Ms. Tanner: Do they look like any other animals you know?

Student: Yes, a pig.

Ms. Tanner: They are related. What do you notice about their fur?

Student: It's all curled.

Student 2: That one's fur is all sticking out.

Ms. Tanner: Those are called twirls. There are different kinds of guinea pigs. Some have straight hair and some have curls — just like people do.

Student: Curls!

Ms. Tanner: Some have short hair like cats and some have long, fuzzy hair.

Student: Is it all right if I bring my cat to class?

Ms. Tanner: Sometime that would be nice. What's Chris doing now? What is he smelling?

Student: He wants to smell a bit.

The discussion continues. Ms. Tanner asks Tony, a small kindergarten boy, to get his apple core, which Ms. Tanner has saved on her desk. Tony jumps at the chance to become involved and returns with the core. The guinea pigs immediately begin to chew it.

Student: Listen!

Ms. Tanner: What do you hear?

Student: I hear their teeth snap.

Student 2: Can I hold it?

The animals are then passed from one set of arms to another. Meanwhile, the four girls in the class have been sitting on the outside of the circle. One of them complains, "I can't see," but no one moves to accommodate her. She persists, asking several times, "Can I hold one?"

but to no avail. When the circle gradually closes in around the children holding the animals, two of the girls remain in the background watching the activity.

During the next 10 minutes, the class talks about the guinea pigs' claws, teeth, the food they eat and where they live. The noise level rises as work begins on constructing a house out of two cardboard boxes that have just been fetched by several students from a nearby supermarket. When the task is completed, it is time for lunch.

Once all the boys have left, the four girls go back to the guinea pigs. They stand looking into the box. Several touch the animals gingerly. When I ask whether they have held the guinea pigs yet, they tell me that they have not had a chance. I suggest that perhaps they would like to try now, so one of the girls picks up one of the guinea pigs and begins petting it. Another is very hesitant, but manages to pick up the other animal. She holds it far away from her body. The guinea pig wiggles and Ms. Tanner suggests that she put it on the floor and play with it there. She does so, but the animal runs away from her. The child follows it, under tables and chairs. She tries to catch it several times, but it always manages to elude the outstretched, unsure set of hands. Several boys come back into the room, and one of them immediately goes after the guinea pig. "Shall I catch it for you?" he asks, attempting to corner the animal. Immediately the little girl stops the chase. She watches for a short time and then gets up and leaves the room.

During the first three months of the school year, the class performed several measuring and classifying activities in addition to the observation activities. Some measuring was done during the study of apples, when the class used recipes to make applesauce. At the same time, the class also classified (sorted) the apples into the different varieties, and then graphed their results. Ms. Tanner had planned to take the class to an apple orchard to do some observation activities, but rain and cold weather prevented the trip. She says she also would like to take the class to the seashore to observe the "sea creatures" but she is worried about being able to control some of the students along the seashore.

Ms. Tanner describes her efforts to develop students' science process skills as "whatever comes up in the context of what [the students] are doing," although she does specifically plan some classifying activities for the kindergarten children as part of their mathematics program.

The science that flows from Ms. Tanner's program centres around the life science areas. Physical science activities are conspicuously absent. A water table sitting empty, covered with a board which is used for storage, reflects this situation. Although the water table is not being used for activities such as sinking and floating, Ms. Tanner does plan to use it to hold tadpoles during a study of "animals in springtime." Hands-on problem-solving activities from a science perspective have not been included in the program either. However, as Ms. Tanner says, in trying to develop a program for children at three grade levels, with many children having difficulty coping with a school learning environment, "there just isn't time to do everything."

Teaching Grade Five

Mr. Blake

Mr. Blake's strong academic background in science is indicated by the fact that he holds a BSc degree and has completed course work towards the MSc degree. He was involved in government research work before entering teaching 14 years ago. His six-month teacher education program did not include a "thorough" science methods course. His personal reading list, which consists of some 20 science-related periodicals, includes publications such as *Science '82, Discovery, Scientific American, Popular Science and Technology* and *Computers and Computing*; for his students, he subscribes to *Owl, Chickadee, Ranger Rick* and *Contact*, among others. He feels that it is his background in science, together with his sustained interest and active involvement in science-related activities, including work with computers, that contribute to his reputation as a "science expert."

While Mr. Blake feels very confident about his science background, he would like to improve his skill in organizing the classroom for alternate ways of learning. He finds that, in general, students are becoming less interested in school learning of any kind and increasingly difficult to motivate. This situation causes him much distress, and sometimes he becomes very discouraged with teaching. He wishes help were available in the form of workshops or courses, but to date he has been unable to locate any. In the meantime, he attempts to adapt as best he can, but continues to feel that what he is doing is inadequate.

Mr. Blake has placed his desk at the back of the room, in a corner where it is sandwiched between several cupboards to the side and rear, and students' desks to the front. Being constantly on the move interacting with students, he does not spend much time at his desk. It was from this vantage point that I carried out much of my observation of science activities in his classroom.

Creating an Investigative Environment

Over a period of several months, this classroom has become a stimulating environment, with an array of living organisms and with a variety of children's work displayed on the walls and hanging from the ceiling. Very little teacher handiwork can be seen anywhere, reflecting Mr. Blake's philosophy that the students learn best from producing their own work, whether it be the morning news broadcasts that his class regularly produces, material for classroom walls or the Christmas concert. As for student input, he says:

"I am very proud of them [for their morning broadcast production] because I know it's not me. It would be so easy for me to write something out for them and say, 'Here, you say this, you do this and that.' It would be so easy, it really would. I would rather see kids make a flop, knowing it was their own effort, and see them take pride in whatever they do, rather than watch them spend all their time doing what someone else prepared for them."

Two guinea pigs occupy a permanent position in the classroom, although other animals brought in by the students periodically join them, as do bits of interesting organic material that students find and want to share with the class. Across the room, near the window, are several large plants, while a fish tank holding guppies rests on a window sill at the back of the room. According to Mr. Blake, living organisms serve several purposes in his classroom:

"I guess one purpose for having them here is to take the edge off the formality of the classroom – like the plants and the fish – there's something in the classroom other than the walls. Secondly, a lot of kids learn incidentally from it. With the guinea pigs, for instance, the kids pick them up and look at them and see their teeth and such. They ask questions about them. It takes a long time to get their curiosity up, you know. Some kids have been curious about the shape of the pellets that the guinea pigs produce. 'Why is that?' they ask. 'What goes in looks almost like what comes out! Same colour.' So, I get into talking about the reasons for that. And, likewise, the fish are a source of curiosity and observation. One student asked, 'Well, are those fish eggs down at the bottom?' and I said, 'No, guppies don't lay eggs; they keep their eggs inside of them.' So we go on to talk about that. Different kids come up with different questions over a period of time."

On the counter that lines the wall on one side of the room can be found some interesting materials — such as a bone, a piece of grass or an insect in a jar — brought in by Mr. Blake or by a student. On display at the moment is a wood borer in a jar, accompanied by the question, "Why such long antennae?"

All material brought into the classroom must be accompanied by a question. Mr. Blake wants the students to think about what they see rather than just make superficial observations about it. He feels that questions stimulate their thinking and, indeed, students can be observed stopping to study the object and spend a few minutes pondering over the question. Mr. Blake feels this exercise has some merit:

"If you just put stuff out, it probably will get looked at and some kids will ask questions and some won't; and I don't really care if everybody asks the question of themselves or not. If *one* does, I feel I have accomplished something."

Students who bring in their own specimens are especially keen to have others observe their contributions. One student recently brought in some teeth from a pig. He arranged the teeth neatly on a piece of paper and added the inscription, "Teeth from a Pig: 1. What type are they? 2. Is a pig a herbivore?" The student was anxious to have me take a look at "his" teeth, so he came to the teacher's desk and extended a special invitation to see what he had brought to class. As he arranged the teeth in the order in which they are found in the pig's mouth, he proudly gave me a private briefing about "fangs" and other "front teeth," as these terms apply to pigs.

This kind of activity reflects, in one way, Mr. Blake's goal for his students in science:

> "I want them to be curious; I want them to be investigative and to develop skills in [science]; I want them to be able to have the challenge of trying to figure out something from the facts they have. To me, that's the basis of all education, and I think science is education, really. The goals I have for science are the goals I have for everything I do — having this sort of love of wanting to find out."

Another way in which Mr. Blake attempts to foster an investigative questioning attitude is to model that behaviour — something he does continually. When talking about a topic, he often injects questions such as, "How do you think that got to be that way?" or, "Look at the information you have; how does it fit in with what you know?"

Although Mr. Blake does have a great deal of scientific knowledge to offer, he tries, nevertheless, to convey the message that he does not have all the answers. He does this by responding to questions with several possible answers.

> "I never give them a definite answer; I always give them two or three answers or possibilities. They know that I don't know the answers. You know, I don't think that there is any 'one answer all the time' sort of thing anyway. I don't know if it is a good technique or not, but I always feel comfortable in doing it. It's arousing curiosity, or saying, 'Look, it's not as simple as it seems.' That's the message I want the kids to get from it, and I think they do, you know."

During field work, students are encouraged to study, examine and investigate. Mr. Blake's own investigative behaviour provides a model for the students, and his questions help to focus their observations. For example, while digging in the forest floor, he puts his fingers to his nose and says, "Smell your fingers; what can it tell you about the ground?" Walking through an area of pine and spruce trees and stumps, he stops, comments and then queries: "Thinning. Why do you suppose they had to do that?" His question led to closer observation of the amount of shade being provided by the trees and to speculation about its effect on new growth.

A Storehouse of Information

In addition to his investigative behaviour, Mr. Blake brings to the setting a wealth of scientific information. He is a virtual storehouse of interesting facts that provide a rich contextual background to whatever is being discussed. Thus a question by a student usually elicits not just a simple answer but elaboration and clarification as well. For instance, during a class in which students were preparing to go outside to collect materials for a forest-floor terrarium, it became evident that some of the students were a bit unclear about the meaning of "terrarium."

Mr. Blake: I think there is some confusion here. What does "terrarium" mean?

Student: Sort of like an aquarium?

Mr. Blake: In a way. What does the word 'terra' mean?

Student: Life-like.

Mr. Blake: No. [The guessing continues.]

Student: Death-like.

Mr. Blake: Terra has to do with the ground, the earth. Terra Firma.

Student: What about pterodactyl?

Mr. Blake: I don't think it comes from that; that's another terra, "pt," and that means winged. This terra means the earth. So, the terrarium is earth, like aquarium is water. Terra is earth, and terrarium is just making a noun out of it. Would someone like to look up the origin of the word? [Researching using resource materials is a frequent occurrence in this classroom.]

Similarly, during a class discussion following an investigation of the living organisms found in different ecological areas near the school, the concept of life cycles was being examined. One student announced that he had found a grasshopper in a grassy area his group had been examining.

Mr. Blake: Grasshoppers. Where do you think they lay their eggs?

Student: On the grass near the ground.

Mr. Blake: Yes, they do. A grasshopper is an insect that has different stages in its life, too, except that it only has baby grasshoppers and then the grown-up grasshoppers; there aren't any larva grasshoppers. The eggs hatch out into a baby grasshopper, and then the baby grasshopper becomes a little more grown-up, and then a little more, and it finally becomes an adult. Now that grasshopper there is just about to moult; as you see, its skin is quite dark. It is just about to moult and become the final stage of the grasshopper — the winged-flying stage.

Student: It's flying now!

Mr. Blake: It's flying now? O.K. Then it is really coming to the end of its life; it probably is just about to lay eggs and maybe it was laying eggs when you captured it. O.K. I'll investigate it a little more fully for you afterwards and tell you a bit more about it. We will look at it under the microscope.

Student: If grasshoppers lay eggs in the grass, don't they get stepped on?

Mr. Blake: Well, they are so very tiny; see, actually they lay them in the ground. They burrow a little hole and just lay them in the ground. The eggs are so tiny it wouldn't hurt just to step on them because they are so small.

Mr. Blake considers factual information of a scientific nature important for students because he feels it provides them with a foundation upon which to build. It is important because, as he says:

> "What is it you want them to know, anyway? They've got to have a lot of these building blocks of knowledge before they start thinking about something else anyway. They have to have the language before they can talk. They have to have the words before they can speak the language."

Although Mr. Blake's explanations provide a wealth of information and a colourful context to almost any discussion, they can lead to a situation which tends to become teacher-centred and content-oriented. As a result, Mr. Blake often ends up by dominating the discussion or answering his own questions, particularly when a student is slow to respond or does not answer correctly. Very short wait-time between question and answer results in classroom interaction moving in the direction of a teacher-centred monologue. Although the ideas being discussed may be informative, an unintended outcome is the loss of the child-centred inquiry environment that Mr. Blake would like to foster. This situation also makes it difficult for many of the grade 5 students to keep their attention on the task at hand, particularly over long periods of time.

Methods of Instruction

Of the five general activities of reading, discussing, recording, listening and experimenting that often occur in science classrooms, Mr. Blake estimates that discussion probably happens most often during his science class, followed by listening, experimenting, recording and reading. When I asked a group of students to state their perception of what happened most in science class, most of them mentioned listening and discussing, and all of them indicated that they would like to do more experimenting. Observation supports the perception of both teacher and students. A great deal of discussion occurs, with the students doing most of the listening. Mr. Blake says he, too, would like to have the students actively involved in investigations on a more regular basis. Sometimes, however, he finds it difficult to organize many activity-oriented experiences. He explains the dilemma:

"I would like to approach science as being an activity, but I'm not always able to do it. I guess it goes back to my organization. I have found that I have to strike a balance between what I think I should do and what I can do. I feel if I put everything into my teaching, what I believe in and feel that I should do, I couldn't do it all. It affects science because I don't plan as much; I don't organize as much as I would like to do. I have to make compromises. The compromises I make are having a lot of lecture-type lessons rather than activities. I'd say out of five science lessons I think there are three activity lessons and two lecture or two reading or two problem-solving lessons — nonactivity."

He also feels that the biological topics in *STEM* that he has agreed to teach (classification, interdependence and communities of living things) do not lend themselves to as much experimentation as do some of the topics in the physical science areas, such as electricity and light. Although he has built into his program a number of activities that utilize the outdoors and his specimen collection, he still finds that it leaves a great deal of material to be covered through discussion, filmstrips, the textbook and other written resource materials.

For Mr. Blake, the outdoors is an extension of the classroom and a rich source of data for a variety of investigative experiences. He finds that students come to grade 5 with little prior experience in investigating, as evidenced by their lack of investigative skills. When asked about this, the other teachers in the school said they rarely use the outdoors for science purposes. One teacher mentioned that she does not take her students outside because "they don't know how to behave" and are too difficult to manage. Consequently, Mr. Blake has had to begin developing in his students the basic skills for learning and investigating outdoors. He accomplishes this in several ways.

Initially, activities are carefully structured so that each group of students has a specific task to do in a specific area within a limited time period. Depending on the activity, Mr. Blake will give suggestions about what and where to explore. Once outside, he models for them the behaviours of an investigator, by making observations, looking for relationships, asking questions and searching for clues in the environment that might provide possible answers. It is Mr. Blake's hope that over time the students will learn from his behaviour and begin to imitate him.

Although he considers these skills very important for purposes of teaching and learning science, Mr. Blake does not teach them directly. Rather, he expects that the students will develop them by being involved in activities in which they will have the opportunity to use them:

"I don't actually teach process skills; I guess they sort of happen as the students go along. I hope that with enthusiasm and my approach they are sort of following along with what I do. For instance,

> I'm observing and I am hoping that they sort of pick up my observational patterns, or how I investigate."

Although Mr. Blake feels that many students have much to learn, he is beginning to see a carry-over in some of them. He recalls a recent incident:

> "I see some of the kids sort of investigating things. For instance, I see them trying to figure out why the guinea pigs are both going in the dark a lot of the time. First, they think it is because of the food, but they check this out and find there is no food in there, so they look in the hole and think a little bit about it and then they look in the hole in the other side. 'It's small! Maybe they like being in small places,' and that sort of stuff."

As a regular participant in science classes over a four-month period, however, I was unable to observe much evidence of carry-over to student behaviour. Perhaps a visitor would be able to observe such changes near the end of the school year.

Mr. Blake associates psychomotor skill development with manipulation of large pieces of equipment such as microscopes and balances. To date, he has not spent much time developing these skills in his students. Mr. Blake offers this explanation:

> "We didn't have the equipment until this year. We've tried the binocular microscope. I've had them out a few times, but I realized that the kids who were working with them didn't have a line about what they were doing. I am going to have to spend some time with microscopes and just let them play around with them. I will get some stuff that I know they could readily see, like leaves, parts of leaves, and we will just look at a whole bunch of stuff. We'll look at chalk dust, look at sugar, salt, all kinds of stuff, and spend the whole afternoon because there are enough microscopes in the school for everybody."

As well, Mr. Blake has not emphasized the development of manipulation skills such as building and assembling simple pieces of equipment as part of his science program, although such activities may "happen" occasionally. As he noted, however, the biological topics currently being studied do not lend themselves particularly well to activities of this sort.

Computers in the Classroom

A year ago three computers were acquired by the school through the efforts of Mr. Blake, who obtained a professional development assistance grant from the provincial teachers' union. Two terminals are housed in the library, a central location that makes them easily accessible to all teachers, although Mr. Blake continues to be the primary user. Being a computer enthusiast, he spends many hours developing programs for classroom use or just investigating the parameters of the system. Mr.

Blake has offered to instruct the other teachers in the use of computers and hopes that some of them will become involved.

Mr. Blake's long-term goal is to acquaint all students with the computer by the time they complete their elementary schooling — not necessarily to make them proficient, but rather to provide them with basic computer awareness that can be expanded later. The most important aim is to make students feel comfortable with the computer.

In the meantime, Mr. Blake has one terminal set up in his classroom for use by his grade 5 students. During the first few months of school, the computer was introduced as a reward for doing good work, so initially only a few of the better students who expressed an interest began learning to use the computer. Consequently, several other students, who also wanted to get involved but who had difficulty completing assignments or who were irresponsible in relation to their obligations as class members, were denied early access.

Instruction on the computer began, therefore, with the training of four or five of the better students. Once these students had demonstrated that they "could be trusted" and had gained the basic skills of entering a simple program, they were encouraged to help other students get started. Mr. Blake feels this cooperative method of peer instruction is both an effective and an efficient way to introduce students to computers. Students are assisted in their learning by written instructions which Mr. Blake has developed and, because he is always in the room to assist in time of difficulty, any problems that arise can be identified and dealt with immediately. Mr. Blake feels that this system fosters success and minimizes frustration.

Girls and Science

Mr. Blake notes that the boys seem to be more interested in the computer than are the girls. No girls were among the initial group of students who learned to use the computer, and seldom were any girls observed to "hang around" the computer during out-of-class time. On the rare occasion that a girl was observed to look over the shoulder of the boy operating the computer, she never asserted herself to get in line to use it, whereas the boys would often haggle over who was next in line. Mr. Blake says, however, that he has the same expectations for the girls as he does for the boys — to become familiar with the computer. He notes that, although few girls resist the expectation, none seems particularly interested at this time. He did discover that one girl was very apprehensive about getting involved, because she had been cautioned against it by a parent who was concerned that she might break the machine and have to pay for it. (The same student was also reluctant to use hand calculators.) Once this misunderstanding was straightened out with the parent, the girl agreed to try. At first she appeared somewhat nervous; nevertheless, she seemed pleased with herself as she sat in front of the terminal while several other students looked on.

In Mr. Blake's view, it is not just in relation to the computer that the girls do not seem as interested as the boys; the same is true of science in general. He feels that, although the girls are just as capable as the boys, they just do not demonstrate any particular interest in scientific endeavours, and he attributes their lack of interest partly to the "socialization process."

> "For boys, science is part of their lives; science is part of their growing up. When they are little boys, they are investigating how the little trucks move in the sand or whatever, and investigation and observation are very much a part of their everyday play. Girls usually are not into those things. They seem to become more interested in dolls and things, and are not into mechanical, investigative, observational things."

This lower level of interest on the part of girls can also be observed in other ways. Although there does not appear to be any explicit resistance to science by any student, it is the boys who outwardly express excitement about science. For instance, my frequent visits to the school soon became associated with science class, and my appearance often seemed to act as a catalyst for remarks such as, "Oh boy, we have science today!" No girls were ever observed to react in this way. Several of the boys were also overheard to remark that science was their favourite subject.

Interest in science is manifested by the boys in other ways, too, such as by bringing animals to school, by frequently spending free time with the guinea pigs and making observations about them, by observing the fish tank or by bringing objects to class which become part of an investigative problem in science. A number of boys also appear to be more enthusiastic towards class activities, as evidenced by the speed with which their hands are raised and vigorously shaken in response to a question, and by the frequency with which they respond.

One group of four girls who shared a table provided a good source of observation over a period of several months. Although the group appeared to be fairly conscientious in completing tasks and following directions, all of these activities appeared to be carried out as a matter of course. There was neither resistance nor excitement, only a routine which happened every Day 1. These girls would find things to do other than science. However, just when one might think that they were paying little or no attention to the ongoing discussion or activity, one of the girls would raise a hand in response to a question. Seldom were these girls unable to respond to a question when called upon by the teacher. On the other hand, even though some of the boys were observed to "tune out," most of them participated on a more active level and with greater enthusiasm than did the girls. Although Mr. Blake is aware of the girls' attitudes towards science, he has not attempted to involve them in any special way so as to cultivate in them a greater interest in science. Similarly, he has not made any extra effort to motivate those boys who show little interest in science. Consequently, the boys who are enthusiastic about science and actively pursue it continue to receive more attention from the teacher.

A Typical Day

It is 8:10 a.m. and Mr. Blake is already at his desk, reading over his notes for the day's classes. He has been at school since 7:45 a.m., his usual arrival time. Following his normal routine, he has spent the first 25 minutes in the staff room chatting with colleagues. Once he gets into the classroom, there will be little time to engage them in conversation until well after classes close for the day. By 8:15, the first students begin to drift in. Mr. Blake, who is now busily gathering and organizing mathematics materials, greets them. One student stops at the guinea pig box, which is kept on a table just to the right of the door. Noticing that the two furry creatures have been separated and placed in individual boxes, the youngster asks why. Mr. Blake, who is now over at the computer, explains that the young female of four months had babies the night before, but because "she was too young to have them, the babies were born dead." The other students in the room all turn their attention to this conversation and several pairs of eyes grow large, while another student displays a look of puzzlement. Mr. Blake continues, "She needs time to recuperate so it is better that they are kept apart for awhile." John, the boy with the puzzled look, inquires further, "How long do they carry their children?" but by now Mr. Blake is busy with a computer problem and the question is left unanswered. John does not persist but continues watching the guinea pigs, petting them now and again.

Paul, another student, has arrived and requests permission to use the computer, which is located in a sheltered corner in the rear of the room between Mr. Blake's desk and the storage cupboards that line one wall of the classroom. Paul is one of a group of three or four boys who often can be found "hanging around" during free time, hoping for a chance to use the computer. This year, Mr. Blake has decided to give more attention to the better students, like Paul, in order to challenge them:

> "I've been thinking a lot this year about the mediocrity in the class — teaching mediocrity. I'm not going to do that anymore. I'm going to push the most intelligent ones, the more gifted ones. If the others want to pull up, fine. You know, I'll get them to a certain level, but I'm not going to teach for nothing. I'm going to push as much as I can, strive for as much as I can."

Paul is now sitting in front of the terminal busily punching in commands which will activate the game that is currently on the disc. Several other students look over his shoulder as he verbalizes the commands, which he reads from the direction manual that Mr. Blake has written for his students. Once the game is activated, everyone takes delight in his attempts to shoot down the invaders that crisscross the screen.

By the time the first bell rings at 8:35 a.m., most of the students are already in the classroom, where they spend the next 10 minutes busily chatting and getting themselves organized for the day. These activities are brought to a close by the intervention of the principal's voice over the PA system at 8:45 a.m. Following announcements and the national anthem, the day's work begins.

It is Day 1 on the timetable, and the students quickly gather their belongings and line up for physical education class, which is held in the gym. For the next 45 minutes, Mr. Blake has a quiet time in which to continue his preparations for the day. The remainder of the morning will include mathematics and reading, according to the timetable shown in Table III.1.

Table II.1 – Timetable for Class Five, Seaward Elementary School

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
8:40	←------------------- Opening ---------------------→					
8:45	Phys. Ed.	Math	Phys. Ed.	Math	Phys. Ed.	Math
9:30	Math		Math		Math	
9:45		Music		Music		Music
10:15	←------------------- Recess ---------------------→					
10:30	←---------------- SRA (reading) ------------------→					
11:30	←------USSR ("uninterrupted sustained silent reading") --------→					
11:45	←-------------------Lunch --------------------→					
12:10	←----------------- Activities --------------------→					
12:50	←----------------- Listening-------------------→					
1:15	Science[a]	Writing	Art	Grammar	Soc. Stud.	Language
1:45		French		French		French
2:15	←-------------- Shared Reading-----------------→					
2:30	←----------------- Clean up -----------------→					
2:35	←-----------------Dismissal-------------------→					

[a] Although science is officially scheduled for one hour, science class oftens starts 10 to 15 minutes early. Additional unscheduled time is also devoted to follow-up science activities; mathematics, language arts and social studies activities are frequently integrated with science.

Except on Wednesday, when he is called on to supervise the hall, lunchroom and playground, Mr. Blake spends part of every noon hour running outdoors, either with the running club (which he supervises) or by himself. Following his half-hour run, Mr. Blake is usually back in his classroom before 12:30, when he finishes his lunch and organizes for the afternoon. Because science is on the timetable for the afternoon, he removes several microscopes from the cupboards and places them on the counter, ready for use by students in examining the seeds they will collect as part of their science lesson. One boy who has just come into the room notices the microscopes and says, "Oh! microscopes," takes a hurried glance, and proceeds to his desk.

Although this is the first time the microscopes have been out this year, the appearance of yet another new piece of equipment or material is not something new; in fact, it is a regular occurrence in this classroom. For instance, sitting on the counter top are several large cardboard boxes full of skeletons and bone fragments that Mr. Blake has collected and prepared over a period of several years. These materials recently were used by the class during their study of vertebrates, and their availability enables the students to stop by and continue their examination at any time. A large insect collection, containing hundreds of carefully mounted and keyed specimens, has already been put away for safekeeping. Perhaps it is Mr. Blake's ability to continually produce from the cupboards collections like these (in addition to a large variety of other science materials) that contributes to the look of awe that appears on the faces of students nearly every time something new is pulled from a shelf at a moment's notice. Certainly it contributes to the sense that science is an integral part of the classroom.

At 12:45 the bell rings, and within five minutes everyone is in the classroom ready for the afternoon session, which begins with a 25-minute listening period. The listening period may include a discussion of some topic of mutual interest, listening and analyzing music or just listening to a story. Today Mr. Blake is reading a chapter from *Charlotte's Web*. The class listens attentively and, at one point, gets into a discussion about runts, during which students learn a few biological facts in addition to the relation of runts to the story line. At 1:15 the relaxed atmosphere is changed as students begin locating their science scribblers.

The class has just finished a study of scientific names and is about to begin some work with seeds – "how plants reproduce and make new plants." Mr. Blake informs the students that they will be planting seeds in order to investigate the conditions under which they grow, and that they will "make all kinds of little experiments with bean seeds because they grow fast." Today, however, the objective is to examine some common seeds that the students will collect from outdoors. As background information, Mr. Blake tells the class that birds may have taken many of the seeds, and because the spring-flowering plants and most of the summer-flowering plants are already in the ground or starting to grow for next year, these also are not available for gathering.

For science class, the students are organized into six groups. Each group is now given the task of collecting a specific kind of seed, and everyone is told to report back within 10 minutes. At this point, the class (including Mr. Blake) departs for the outdoors, where each group moves off in a different direction and busily begins collecting its seeds. When the time is up, everyone returns to the classroom for the remainder of the lesson.

Once in the classroom, three binocular microscopes are placed around the room so that the seeds can be examined more closely. Each group of students is asked to locate the seeds in its plants and make some of the seeds available to the rest of the class. The students are then told to make a collection of the different kinds of seeds and paste them on a piece of paper in their notebooks.

The students eagerly set to work trying to find their seeds. Some pound their specimens, while others pull apart flowers and disassemble cones. Moving about the room, I notice that most students are not able to identify any seeds. Conversation reveals that they don't know what they are looking for. Instead, they just make a guess, with the result that flowers, seeds and parts of plants are all pasted down together. Mr. Blake, apparently aware of the general problem, interrupts the class and asks for attention:

> "Now, some people have been fooled this afternoon in looking at seeds. They are looking at the whole flower thinking it is a seed, and not until they put it under the microscope did they discover it was actually just a little tiny speck. Now, this microscope has some of the little tiny seeds and some flowers, so some of you may want to come along and see it."

Several students gather around the microscope waiting for their turn to have a look, and Mr. Blake continues to circulate around the room, giving assistance to each person at a microscope. In nearly every case, he has to locate the seed, and even then students continue to be confused, asking, "But which thing is the seed?" or "Where is it?" Meanwhile, the rest of the class continue taping and pasting in their notebooks or struggling with the microscopes. Some five minutes later, Mr. Blake once again asks for attention, goes to the chalkboard, and begins "describing a few things" that he has noticed about the seeds he has seen, drawing diagrams on the board as he speaks.

> "A spruce seed looks like a little wing. And all the fall flowers come with all kinds of seeds — some tiny, some circular; some with little twirls, and two parachute seeds like this; some seeds look like little sculptured nuts; and some plants come with long seeds. We had one kind of grass seed that was very small. Did anybody find any other seeds?"

No one had, so Mr. Blake moves back among the students and everyone continues working. Some students now try to identify seeds similar to the ones drawn on the board. Mr. Blake continues his rounds, all the while explaining, clarifying and helping students identify their seeds. I, too, move about the class, talking with students about what they are doing, assisting periodically with a microscope or stopping for a look at what students are examining. Although many of the students still have not found their seeds, their failure does not seem to bother them, and they continue the task of pasting and taping — a task which appears to be the primary concern for a number of them. Some students who are having trouble with the microscopes finally give up and go back to their places, but a few persist, determined to locate some tiny seeds.

To date, the class has had no special instruction in using a microscope; trial and error tend to predominate. This process continues for another 20 minutes, after which students are asked to return to their places and give their attention to the front of the room. Gradually, the activity and the chatter cease, and Mr. Blake begins guiding the summary:

Mr. Blake: We saw a lot of different things, and now we are going to try and figure out what's happening. The seeds we saw were tiny, more or less like the ones in the chart [points to drawings he has made on the board]. I have no idea what some of them are. It's very difficult to identify some of these plants, because usually we look for flowers and leaves; there are none there. I've been fooled so many times by looking at a plant that I don't even try to guess any more, because they're so different from when they have their flowers than when they have just their seeds. O.K., what are some of the characteristics that you noticed about seeds?

Student: They're small.

Mr. Blake: Small. Yes. In fact, some of them you could even say are. . . .

Student 1: Tiny.

Student 2: Microscopic.

Mr. Blake: Yes, there might be some that are microscopic, because we couldn't really see them until we had the microscope on. Why? What kind of adaptation is it for a plant to have tiny seeds?

Student: Well, I think so there can be a bunch in the flower and so the birds won't get them.

Mr. Blake: O.K., so maybe they can escape detection by birds.

Student: So they can fall on the ground easier.

Mr. Blake: All right, so they can fall in the little crevices in the ground. These are all possible reasons.

Student: Maybe nature just made them that way.

Mr. Blake: That may sound sort of funny, but just think of it. They don't have to be big; maybe it's more economical to be small. What does a seed do?

Student: It grows.

Mr. Blake: Let's think of what seeds do. What is job number one? Actually, job number two is related to job number one.

Student: Grow up.

Mr. Blake (clarifying): Grow a new plant.

Student: Makes new plants?

Mr. Blake: No, that's the same thing. Job number one was to grow a new plant. Job number two relates to that. There is something else the seed does. We eat seeds.

Student (surprised): We do?

Mr. Blake: We're almost there.

Student: Food?

Mr. Blake: All right, job number two is to store food. For whom?

Student: The plant.

Mr. Blake: Right, the new plant can't make its own food, can it? Does it have leaves? It just has a little stalk coming up through the ground, so it has to have food until it can grow and make its own food. So a seed has two jobs; it has a job of storing up food and a job of having that little bit of life in it that will start a new plant — the cells or whatever. Now, when they opened up King Tut's tomb, they found seeds in there and scientists planted some of them and they grew. They had been buried for thousands of years. Now, one of the most long-lived plants — and for that reason it was very often made into a little necklace, in a little globule of glass — is the mustard seed.

The mustard seed can live for hundreds and thousands of years without dying. Some seeds won't; some seeds will hardly live from one year to the next. When you plant lettuce and count how many seeds germinate, from the lettuce, you'll find that only about half of them will germinate, and next year, if you have the same package of lettuce seeds, you'd probably get ten out of it. So they don't last very long.

Student: What about those seeds that have milk inside of them? Does the milk provide food for the seed?

Mr. Blake: Coconuts?

Student: No. Sometimes you find some of it in dandelions.

Mr. Blake: No. There wouldn't be any of that in it at the beginning; that would be manufactured. It's the fluid that moves up and down the little tubes in the plant, a bit like sap. Arnie?

Arnie: Well, how about the lotus plant?

Mr. Blake: Well, I don't know about that.

Arnie: Well, they found it frozen for hundreds and thousands of years so they put it in boiling water and it opened up.

Mr. Blake: I don't know about that. Some seeds preserve just a little bit of life, and there are some animals like that too. If you put dried-up weeds from ponds in water, you'll often see some little animals begin to swim around.

By this time, it is nearly 2:30 and time to get ready for dismissal. Everyone begins to clean up and reorganize the classroom so that it will be in order for the next day.

Once the bell rings, nearly everyone leaves. A few boys stay to use the computer. Mr. Blake talks with them while he tidies up from the day's activities. By 3:15 all the students have left, and Mr. Blake finally has some quiet time in which to plan and organize for the next day. This year he stays until his work is completed, a departure from previous years when he often took books home with him so that he could work several hours each evening. The pace he was keeping was leading towards "burnout," and he was forced to re-evaluate his priorities and reorganize his time. Now, he stays later at school, until 5:30 if necessary, in order to complete his work and not have to take any home with him. He still worries about burnout though, but at least things are "a bit better" this year.

III. Science Teaching at Trillium Elementary School

Thomas Russell and John Olson

This is an account of the work of three elementary school teachers at a school in eastern Ontario, which we have called Trillium Elementary School. Readers are cautioned to resist the temptation to generalize from the work of these teachers in one elementary school to the work of many teachers in schools across Ontario and Canada.

Mr. Swift teaches science exclusively, to a number of different groups of children; Mrs. Macdonald and Mr. Clark teach science as part of their broader responsibility to direct the entire curriculum for one group of children at a particular grade level. All three volunteered to take part in this case study, and thereby indicated some degree of comfort with the teaching of science and a belief that the year would permit them the time and energy to submit their teaching to an unusual type of scrutiny.

Trillium Elementary School was built in 1958; inside the front door, a plaque commemorates the opening. The building of the school reflects the suburban growth of the city. Most of the children come from middle-class homes, from parents who, by and large, expect their children to do well in school and who support its work. About 250 children in kindergarten to grade 8 attend the school. Mr. Swift is the vice principal; his time is about equally divided between administrative duties and teaching grades 7 and 8 science to classes that rotate among several teachers for different subjects. These classes have four 40-minute periods of science in a six-day cycle. Mr. Clark teaches grade 5, and Mrs.

Macdonald teaches grade 3; the science they teach is included in that portion of the curriculum called Social and Environmental Studies (SES).

Science in the Intermediate Division

Mr. Swift joined the school in 1972, when he took charge of the science program in grades 7 and 8. At that time, local control of the curriculum was the policy of the Ministry of Education. This policy had, in fact, been established that very year. Prior to that time, the nature of the science curriculum had been specified in some detail; however, the 1972 ministry guideline did not mandate material to be covered. The document did outline the curricular policies of the ministry in general terms and included illustrations of how these policies might be realized through local action. Thus Mr. Swift was left to his own devices when it came to planning the program for the school.

The science room as he found it then was much as one finds it today. There are six three-bench groupings, each seating six students who are organized as a team; one student in each group acts as the leader. Along the south side of the room is a work-bench with six sinks; above the work-bench are cupboards containing class sets of two textbooks written to conform to the pre-1972 guidelines. As well, there is a half-class set of textbooks written according to the 1978 guidelines, which reintroduced considerable content specification as part of the curriculum policy of the ministry. In the cupboards are pieces of equipment that were obtained as part of the Ontario Teachers' Federation (OTF) Science Project; the equipment includes metal inclined planes, metal test tube racks, test tubes and flasks. These OTF units were developed for use in the elementary schools in the 1960s and early 1970s. The project was a major effort at elementary school science curriculum reform.

On the wall opposite the cupboards are a small chalkboard, a noticeboard containing information about science fairs and, beside that, the door to the preparation room. This room contains, among other things, six OTF balances, six Bausch and Lomb junior microscopes, a number of OTF tripod stands and three OTF alcohol burners. Also stored in the room are kits of materials assembled by Mr. Swift to go with some of the units he now does in science. At the front of the room behind the teacher's desk is a chalkboard which is usually covered with notes, including definitions and diagrams.

On the chalkboard next to the noticeboard is the program of units to be covered that year. Grades 7 and 8 do the same units each year; each unit is taught every two years. The cycle is currently at Year II. In Year I the following units are covered: "Classification of Living Things"; "Interdependence"; "Properties of Matter"; "Measurement I"; "Science Fair"; "Science Happenings." In Year II of the cycle the following units are covered: "Characteristics of Living Things"; "Measurement II";

"Force and Energy"; "Plants"; "Science Fair"; "Science Happenings." A number of units are prescribed by the ministry guidelines, and others can be found in the guidelines but are optional; "Science Fair" and "Science Happenings" are local units.

When Mr. Swift came to the school there were no prescribed units. He tells what it was like then:

Swift: My academic responsibility when I came here was [to develop] science program in the school — there was no science program. It's grown from almost zero. . . . I keep getting a little more each year in that my spread is increasing [to include grade 6]. When I was given the mandate I was apprehensive. [I was told] to do it and do it well. There was no doubt in my mind what was wanted.

Olson: You were concerned from a subject-matter perspective?

Swift: Because of my failings in university science. . . . [But] let's look at another reason why: no real guidelines, as they are today. "This is what they do down at Pine Secondary School." That was my guide.

Olson: Had you expressed a desire to do science?

Swift: No. No one wanted to do science. Even today, if I were to bow out of the picture, I think that science [would decline]. . . . I'm proud of what goes on here. It's not perfect. What I'm doing now is refining, enriching. I include more.

Olson: What did you do about that reticence as you began?

Swift: There was nothing. Nothing.

Olson: No counsel?

Swift: As a matter of fact, what went on in grade 7 and 8 is very much like what I think goes on in primary division. [Science] is done incidentally. A kid brings in a butterfly. We talk about butterflies.

Lacking guidance, Mr. Swift sought out sources of support, including guidelines from other boards, OTF units and workshops, and advice from a local secondary school. Mr. Swift said he was sure that parents now expected the school to do a good job with the science program.

One of the school's recent curriculum priorities has been to ensure that the ministry guidelines for the intermediate grades (7 and 8) are implemented. At the board level there is a superintendent who has science as part of his portfolio and whose role has been to help arrange the county-wide events (such as science fairs) and to encourage curriculum development at the local level, mainly through summer writing teams. A mathematics-science consultant (a temporary resource position in the board) has had contact with the school, particularly concerning the development and use of locally produced units for kindergarten to grade 6. Mr. Swift sees it as his job to make sure that these units are passed along to the primary-junior teachers. In Mr. Swift's view, science is treated as an incidental subject in kindergarten to grade 6. How significant science becomes depends very much on the interests of the person teaching it, he believes.

The advent of the ministry guidelines signalled a watershed in Mr. Swift's career:

> "To me, the ministry guidelines are a godsend; I put a great value on them. Also, because I tend to look at myself professionally as an organized person, I have to break it down into little organized units for me to move ahead and to present the material in an organized form. The philosophy [in the guidelines] goes on and on, and it could be condensed. What to look for is the units themselves. . . . I feel that I'm accountable for what's in the ministry document."

Before the advent of the 1978 document, Mr. Swift said, he was not sure that the tack he took in his teaching was what was expected:

> "If you had nothing to guide you, you can skirt over it [a topic] too easily. When I had no guide, I could take my sweet time and, let's say, do plants all year if I wanted to. . . . [Now] I feel that I'm accountable. I feel that way because at a number of meetings that I was at it was said, 'They're your parameters. You'd better work with them.'"

Goals and Activities of Intermediate Science

Quite naturally, the question "Why teach science?" came up in our conversations. Mr. Swift says that covering the core material in the guidelines prepares the students for high school and that is important. That material has to be covered. The optional material isn't that important. Covering the core must be done so as to reduce the students' fear of science. This fear, he says, is radiated by teachers:

> "Teachers avoided science by hiding it in that mystery called Social and Environmental Studies. . . . I usually have enough indicators to tell me that the kids feel [fearful] towards it. . . . I try to generate [an awareness of] the importance of [science] in their everyday way of life. It's a healthier attitude to it [that I am after]. As far as being able to play with knobs [on the microscope] or look at oscilloscopes or dissecting technique, no."

Mr. Swift speaks of trying to get students to see how science is important in their everyday life. This, he feels, is more important than teaching them how to manipulate oscilloscopes, microscopes and other complex pieces of equipment. One of the ways he pursues this goal is through a local unit called "Science Happenings." This unit is one students study each year as part of the ministry's requirement that six units be covered. At the beginning of the year, the students are given a pink sheet on which are written the criteria for the work. Each month, for example, grade 8 students are required to collect, annotate and place in a notebook 15 science articles taken from the newspaper or other suitable sources. The program runs from September to May. All students in grades 6, 7 and 8 do this unit each year. Seven objectives for the unit are listed, including "to promote the fact that scientific development plays an important part in our lives today and in the future." Mr. Swift is in his second year of the "Happenings" unit. He started the unit as a way of introducing a manageable unit as part of the six he had to complete each year and to show that "Science is part of every day. . . . It's not just in the classroom. . . . I'm a believer [in the idea that] people should know what's going on." He found that the activity had paled a little by March:

> "They were getting sick of it. It went on too long, but it has to; it has to go on to develop some responsibility. . . . Perhaps I'm putting too much onus on the kids. In a way, it's very much like university."

Mr. Swift is doubtful about the value of introducing what he views as complex equipment into his science program. Microscopes, for example, are not essential: "To me a microscope is a complex form of equipment [even] in its simplest form, and to say to kids, 'Here are the microscopes we are going to look at,' and you know [they are] going to go through [i.e., break] the slide. I can't stand this sort of thing." Similarly, other unnecessarily sophisticated equipment is to be avoided:

Olson: You place that [microscope work] later? Grade 9, 10?

Swift: Yes. Look at this morning's work, dissecting lima beans.

Olson: They are doing it?

Swift: Yes, [but] scalpels, I can't afford them.

Olson: What do you use?

Swift: Razor blades, one end covered.

Olson: Every kid cuts up one of these?

Swift: Yes, absolutely. Some cut two or three.

Olson: Draw?

Swift: They draw and identify parts — draw and label. Someone from the university [might say] that's not the way to do it. You do it with a scalpel. [Here] we do a primary [grades] type of thing, hands on.

Olson: So who needs a scalpel?

Swift: What I am doing is fine, even though the razor blades are rusty. O.K., we can't keep replacing them every year. So [I say to them] "Don't cut yourself!"

Olson: So you've had them around for a while?

Swift: Yes, but they still cut. You have those around. That is part of your stock of equipment, of your own bits and pieces.

The practical activities unfortunately sometimes give children a chance to misbehave:

Swift: One particular class this morning doesn't listen to instructions. O.K., you find out that the beans are a little bit slippery so you try to shoot them off through the sky. That annoys me.

Olson: Why?

Swift: I'm sincere about what I do and when I see this sort of thing happening I've had to demonstrate and they watch. I can say, "Yes, it's been covered, but *you* won't have *experienced* it."

Mr. Swift has organized the class to make the best use of the equipment:

Olson: When you are doing activities with kids, what are some of the things you hope they will get out of them?

Swift: [They] hand in things, [and] learn observatory skills [and] care and respect.

Olson: Do they work in pairs?

Swift: No, they work in groups of six. Yes, every class is organized the same way, and I use it for the whole year. It's very mechanical, with a chairman and a vice chairman.

Olson: They work well in these groups?

Swift: Yes, and I find this satisfactory.

Olson: With that number?

Swift: It's a manageable number, and I can go a reasonable way with the equipment. Instead of having, let's say, 18 sets if they worked in pairs, they work with six sets of something.

Olson: So it's economical?

Swift: Oh yes! And the same with the textbook, you see.

Mr. Swift has changed his ideas about how to conduct practical work. Pressures of time have made him modify the way the students proceed, although he continues to stress with them the need to be prepared:

Swift: At the beginning of the year, invariably somebody in each class says, "Are we going to do dissections?" I say, "Well yes." They say, "Whoopee." I say, "Yes it's fun, but we have to study before we start cutting things apart, because we have to know what we are looking for." And that is, hopefully, casting an attitude for secondary school. As far as a write-up is concerned, I used to do a lot more before 1978. I was almost looking for things to fill up the students' time. We did a lot of writing up according to the standard procedure — you know — method, and so on, [and writing] "my prediction" — that was sacred! So in those days there was a lot of writing up, and that took a lot of time. I wouldn't say we wasted time, but it was a way of making that drop of water cover as much of the table as possible. But now I can't afford the time during which I should be covering more material. I'm not sorry we don't spend a lot of time writing up experiments. I feel they'll have plenty [of that] in high school and university. I feel there are too many other goodies [available], a broader knowledge base. The ministry wants us to cover six units in a year. [That] is rather difficult.

Olson: When a group is finished doing some of the things you've asked them to do, where do they go from there?

Swift: We take up what I expect them to have seen; that becomes part of the overall note. In other words, I'm "dictatorial." This report won't be as individualized as lab reports would be.

The notes the students write become the basis of the tests the students write. Why have them write this information down and repeat it on tests?

"It's self-discipline, you know. [They are to] know certain groups of facts. It's laid out at the beginning. There's nothing wishy-washy about it. It's pedagogically important because to operate in a vacuum is sinful. And now that I know I have an indication about what is to be done, let's get on with the task and do it well. So I am a much happier person in class."

Mr. Swift is aware that there is a dilemma for him here. If he does all the things he did before 1978, such as extended practical investigations, writing up experiments, outdoor work and so on, he would not have time to cover the required material specified in the 1978 ministry guidelines. The transmission of this material, in his view, takes priority over a number of other desirable, but not essential, activities. I asked him about this dilemma:

Olson: You said some things about what gets in the way of covering important work?

Swift: I am a convert to the guidelines; the work has to be covered. You as an academic might say, "But these kids should. . . ."

Olson: Do microscope work?

Swift: That really isn't what the ministry means. Let them play around with microscopes? Sorry, but. . . .

Olson: Why do you think it has to be this way?

Swift: Because the ministry wants it. What I see in writing — what I interpret the writing as [saying is] — "Cover this!" and it will be covered.

Mr. Swift prizes the equipment he has collected within his limited budget. He has accumulated a stock of materials which he tries to keep intact. He expressed concern about hanging on to these materials:

Swift: What I have collected, scrounged over the years with a zero budget, I want to get when I want it and in good shape, [I want] to know where it is, take it out, use it and put it back. I keep it under lock and key.

Olson: Any particular kinds of equipment?

Swift: Things as simple as a thermometer, test tubes that don't come back, beakers that don't come back. When I want it, blindfolded I can take it out. I know exactly where it is.

I asked Mr. Swift about the OTF science equipment that he no longer uses. What about the inclined planes? What had they been used for?

Swift: There is something that I spent a lot of time with before 1978. I had a lot of fun with them. You know, some graphing and the rest of it. Now they don't fit; so they collect dust.

Olson: Do you regret not using them any more?

Swift: Yes I do, because it was mechanically oriented, and I like that work. Prior to 1978, it was just another unit. It wasn't planned. A lot of good work was done with them. . . . Currently we're doing leaves. Now we looked at different ways of classifying them. What I'd love to do is to take them out in the yard. Pre-1978, no problem; but now it's going to cost me another lesson [if I go outside].

Notebooks play an important part in the work of the class. The chalkboard, rather than the textbook, is the source of information to be learned. The notebook is the record of the work covered. Mr. Swift has the students divide their notebooks into two parts:

"The front of the notebook is the good part. The back part is where they make rough notes. . . . What's in the back is precious to them. . . . [I say, for example,] 'If you love me on that day put a heart; if you hate me, put whatever you like. . . . You express yourself in those pages. . . . That's an area for free expression. . . . You'd better have a good set of notes from which to study.' And I tell them from my own experience that if my notes were rotten I didn't want to study from them."

The textbooks are sometimes useful, but they are not central to the work. Mr. Swift explained why he preferred to organize the material for the students himself:

"In the transition period [during which there were no guidelines] I learned to use the science books for reference only. . . . I continued that way. [Students] like it that way. . . . [If I used the books] I would get off track from those [notes] I follow. . . . To me, a book is merely a suggestion [for] a new teacher, a green teacher — 'There it is; use it if you need to.' "

Rather than use the textbooks, Mr. Swift prefers to put work on the board: "I like to know that things are going to go well." He does not assign homework from textbooks.

Olson: You don't assign homework from textbooks?

Swift: [You mean] "Read these two paragraphs and answer the questions?" No, sir.

Olson: That's not part of your style?

Swift: No, sir.

Olson: What do you give them for homework?

Swift: [Take plants]. I start off with trying to impress on them that the plant is important to man. So for the next day [I'd say to them]: "I'd like you to bring in, in writing, 10 uses of plants to man and I'd like a direct and an indirect example of those uses."

Olson: So they have to get it out of their own experience, rather than extract it from a textbook?

Swift: That's right. It's that sort of thing or translate a rough note into a good section of the book. The back part is where they make rough notes.

Olson: Do you check the books for homework?

Swift: For homework done? Yes. At the beginning of the year I walk around and look into every book. When I say I want 10 uses I want them there. If [a student says] "I've only got eight," [I say,] "Make sure you have 10 by the time you walk out of here."

Olson: Do you deduct marks for failure to do homework?

Swift: That's correct. If a kid never does homework, no more than 20 marks can be lost. . . . I get some super ones. However, if it is poor, I'll put it on the report card.

Olson: Homework, is it a small or big deal in your scheme of things?

Swift: Small, the completion of work.

Olson: Is class the action centre?

Swift: Yes, that's right. Even finishing off a lesson [I say to them], "This is what I expect of you. If you want to sit and twiddle your thumbs, as long as you don't disturb somebody else, that's fine; but you'd better have it done when you come the next day." Again that's putting more onus on the students. It's getting my standards to stick. . . . I give them time now to do it. The door is open, and [the notes] will be erased at four o'clock.

Teaching from the Guidelines

From our conversations, it became clear that teaching science with and without guidelines are two very different things for Mr. Swift. Without guidelines, what is to be taught is unclear, and it is impossible to organize the material into carefully timed parts. The danger of drift is constantly present when the work is not under the control of some regulation. The 1978 ministry guidelines supplied Mr. Swift with a regulating mechanism — presenting the core material of those guidelines to students. The sheer amount of material, however, creates a situation in which certain activities have to be reconsidered, given the amount of time they require and their tenuous connection to what the guidelines require. Given a budget of limited time and an extensive program of material to cover, the use of time becomes a critical factor for Mr. Swift in deciding how to proceed. Time becomes a factor influencing not only what is presented, but how it is presented. With the guidelines authoritatively prescribing content to be covered, Mr. Swift is left with the task of deciding how that content might best be dealt with. His objective is to cover the material in ways that are interesting but not time-consuming.

The most efficient way to avoid wasting time and yet be able to portray science in an attractive way, according to Mr. Swift, is to retain firm control over the lesson and not spend too much time on discussion or "side-trips." This has meant that what might have been usefully included, if time had not been of paramount importance, has had to be omitted. Some of the things that Mr. Swift has had to omit for lack of time are the pursuit of students' ideas (in some cases), enrichment topics, lab work rather than notes (at times) and field trips. Mr. Swift is aware of the dilemmas inherent in the regulation of time by the ministry guidelines. If the time budget is carefully used, the units are covered; if time is "wasted" on "extras," the units will not be covered. The regulation provided by the guidelines, as Mr. Swift sees it, provides an orderly context for planning — for defining the task to be done and showing what to stress in the time available. Thus the guidelines are a mixed blessing in Mr. Swift's view: a source of authority about what to include and a source of pressure to exclude interesting but time-consuming work. Content information is included; certain time-wasting activities are excluded. The balance isn't perfect.

To pursue in greater depth Mr. Swift's attempts to resolve this dilemma, I asked him to sort statements of science teaching activities, which ranged from highly teacher-controlled activities to student-controlled activities. These statements, which were written on small cards, he arranged in a number of groups according to some underlying construct he had chosen to organize his thinking about the set of 20 statements. We then discussed these activities in relation to the set of constructs he had used to sort them.

One important construct he used to organize the groupings — an overarching construct — was that of "keeping on track" versus "squandering time." He said that all of the activities could be organized along this dimension. Teacher-centred activities were seen to be on-track activities: "I, as the teacher, know where I'm going, and I don't want to be thrown off track too much. I have a definite goal to achieve and a definite amount of time in which to achieve it." The importance of knowing the goal and of planning the time needed to achieve it can be seen in how Mr. Swift views an activity in which students are at work doing an experiment to verify a law. As Mr. Swift sees it, he has limited control here.

> "If a kid messes around for 40 minutes and measures for a couple of minutes, copies and makes up data for the rest of the time, I can't control that part. . . . On the other hand, when I'm in control, the kid may be wasting time if his mind is outside. . . . When people are given freedom, there's a greater tendency to take advantage of freedom, to horse around. I think I've found an answer to this, but I don't think I can live with it."

I asked Mr. Swift to explain what the answer might be to this dilemma. He spoke of problems in approaching a field trip to the Ontario Science Centre. To make sure that time wasn't wasted, he had the students do four worksheets while they were at the Centre. The students complained to him afterwards that they hadn't had time to complete the worksheets. Should they be allowed to go their own way at the Centre and perhaps "squander" their time, or be required to do the sheets and perhaps enjoy the visit less? Mr. Swift is aware that there is an important dilemma here and that he has to resolve it before the next trip to the Centre.

> "There's a lot of messing around. I can't be with each child. What's wrong with messing around in a place like the Science Centre? What happens if they push a button 10 times? Isn't that discovery? I can't argue with that, but I'm uncomfortable with that situation. I guess I have a way of controlling it."

Mr. Swift sees teacher-controlled activities as having a definite goal and a definite time to achieve the goal. If time allows, then students can be involved, but if time presses, "If that clock says I've got five more minutes to get that done so that they can get their notes, I'll eliminate [discussion] and revert to [telling them]. . . . It's safe. I know where I'm going." Mr. Swift talked about "savouring" his lesson time as opposed to having to "cover" the ground:

> "So, let's say the lesson is broken down into four units of time. Let's say an hour lesson, and I've used half the time. One of the 15 minutes I've done in 7 1/2 minutes; now I've 22 1/2 minutes to do the rest. If I get my 15 minutes done there, I may, if I like, have 7 1/2 minutes savouring time. I can do the lesson and enjoy it and spend some time developing an answer from a child. If it goes the other way and [I use more than 15 minutes] then I'll really speed up and go like heck."

For Mr. Swift the guideline regulates the time. It prevents time from being wasted. How does he view those occasions when time is unavoidably lost? Mr. Swift defends his "lapse" of time management: "I must confess. . . . there were a couple of things I did that cost me in terms of periods, say three, four, five periods, but I enjoyed it. Without it I don't think I could radiate any love of what I'm doing."

I asked Mr. Swift what types of activities tend to take more time than they should:

Swift: Showing the film; that's not recorded in the book — in notebooks — as work having been done.

Olson: But was it worth the time to do that?

Swift: I feel it was.

Olson: You are glad you took the time?

Swift: Yes, otherwise I wouldn't have done it. Another thing was the [observation of the structure of a] bean — inside and out. Two periods. "This is your note on the board. This is the way it's going to be. There's a hole under the scar. Take out your lenses."

Olson: So you did get the lenses out?

Swift: That's right; let's have a look at them. I'm taking the luxury of taking the time to explore. Put them [the beans] in the freezer. We'll be back tomorrow. That was a luxury. What I'm saying is what could have taken one period has taken two, but as far as I'm concerned, it was really worthwhile.

Other activities had more potential for the squandering of time, although they could also have benefited the students. Mr. Swift was aware that in stressing "efficient" activities he was perhaps giving up on other things. For example, he had asked students to engage in some thinking out loud, in hypothesizing about something they had seen:

"For the good ones, [this exercise afforded] a chance to participate, a chance to help the teacher, to formulate something; a chance to see his [the student's] idea go on the board when I trigger the idea in him; and it's exactly what I wanted to have anyway."

Field trips present special problems for the efficient use of time:

"This plant unit we are doing: I didn't go out. It would have been a fun period with each class. We may have got it done. I gave it up. . . . One thing we did last year, we went to a creek within walking distance of the school. It did not upset the system, and this is something else you have to watch. You upset the timetable and it snowballs. So that's enough reason for not doing it as often. I shouldn't say that. If I wanted to do it, I'd get it done."

Teaching Core and Local Units

While Mr. Swift and I were meeting to discuss his thoughts on science teaching, he was working through one of the optional units — "Plants" — and one of the compulsory units of the ministry guidelines — "Characteristics of Living Things." I sat in on nine of his lessons associated with these topics. These lessons gave me some idea of what it was like to be working from the 1978 guidelines.

The first lesson I sat in on was concerned with the structure of taproots. A diagram had been placed on the side chalkboard outlining the parts of the taproot. One student was asked to point out the parts of the longitudinal section, and another, the transverse section. Some students had not learned the terms, and Mr. Swift asked them to learn them for the next lesson. They were given a mnemonic to help them remember the parts. The main part of the lesson was to have been a dissection of a parsnip, which had been left standing in dyed water.

Unfortunately the dye had not penetrated the root sufficiently. Mr. Swift asked the students to consider how they could tell if the dye had been taken up. Some suggested that there would be less fluid in the beaker. Mr. Swift suggested there may have been other reasons why the water level might have fallen, and he asked the class to consider these. Following this exchange the class looked at the parsnips, one for each group of six. The students were then brought back together and asked to comment on what they had seen. The shrivelled condition of the roots attracted the students' attention, and Mr. Swift asked them to explain why the parsnips were shrivelled and how that might have been prevented. The 40-minute lesson ended on that exchange and a promise of dissection next week.

A later lesson found the students working on the unit "Characteristics of Living Things." On the chalkboard had been placed definitions of important terms. Students were asked to recite the characteristics, and then the lesson proceeded to the new material — reproduction. After Mr. Swift introduced this topic to the class, they watched a film on plants, and then, until the lesson's end, they made notes from the chalkboard. The following extracts are taken from the grade 7 and grade 8 lessons on this topic. Here we see Mr. Swift introducing the class to reproduction as a characteristic of living things.

Grade 7: 15 Students, Period 1

Teacher: Today, we're going to have another look at the characteristics of living things, and that's reproduction, and we were quickly overviewing the unit. What did we say reproduction means?

Student: Make one like one's self.

Teacher: O.K., make babies. When we make babies, there are two different ways of doing it. One is called sexual reproduction. Sexual reproduction is where we have two organisms making one; in other words, like dogs — the papa dog and the mama dog. The mama dog can't make babies by herself and the papa dog can't make babies by himself. That's called sexual reproduction. Then we have another kind. That's called asexual reproduction, and this is where we need only one organism to make babies. You don't need a papa. The mama does it all. Do you remember one plant in the last unit that could make babies by itself; that could reproduce either way?

Student: [inaudible]

Teacher: That's not the one I was thinking of. [pause]

Student: [inaudible]

Teacher: Yes, that's correct. You are really smart. With asexual reproduction — that's where only one organism is required to reproduce another one. We have two kinds of asexual reproduction. One is called fission — fission; and please if I ever ask you to put that on paper, don't you do it, and I've actually seen this on paper. I've had kids actually put down fishing: gone fishing. Don't put down fishing. It's fission: f-i-double s-i-o-n. Here, an organism divides itself into two new organisms [pointing to drawing on chalkboard]. Perhaps you'll get a better idea by looking at page 20 in *Focus on Science.* Make that page 21. If you have a look at the two sets of gray diagrams, it's the upper set. First you have – what do you call that first thing?

Student: Cell.

Teacher: Who was the first one to say "cell"? Who said "cell"? Was that you, Karen? Oh, super. I think we're looking at an 80 [for you] next time. We have there a cell, and in the second drawing, what changes have taken place in the cell?

Student: [inaudible]

Teacher: Yes, it's a different shape. What changes can you see already? Yes, Curtis?

Curtis: It's starting to get so that when it splits in half, it's equal on each side.

Teacher: Could you be a little more specific?

Curtis: When it splits in half, one side will be on the other side — identical.

Teacher: I think you're saying — correct me if I'm wrong — are you saying that you can see evidence of splitting already starting?

Curtis: Yeah.

Teacher: How? That's what I'm getting at.

Curtis: It's starting to move in.

Teacher: What's starting to move in?

Curtis: The cell.

Teacher: I think we're making a mistake here. This whole thing is the cell.

Curtis: Yeah, I know that.

Teacher: What do we call this thing in the middle — you remember from last day? This thing here. I see a couple of hands up. Yes, sir?

Student: The nucleus.

Teacher: Yes. What's different about this one from this one? You say. . .

Student: In the middle — it's almost coming in.

Teacher: Yes. It's almost like a waistline on a lady. That's the beginning of splitting; and then, of course, in the third one, the diagram shows that the division is taking place; and in the fourth one division has taken place, and each one of those new cells is called a daughter cell. A daughter cell! That doesn't mean that it is a female. That is not the case. It is merely called a daughter cell indicating it is an offspring. That is one way in which it happens. The second way is budding. The bud appears on the parent cell and breaks away, and you can see the different stages. I haven't done it quite as well as they have in the book, but the idea is there — two kinds of asexual reproduction: fission, where splitting takes place; and budding, where one plant comes off the parent cell. In each case, the new cells are called daughter cells. The products of fission and the products of budding are called fission cells. Now, I've summed up our lesson for this morning by saying that some forms can reproduce sexually and asexually, as we've said, but most organisms use one method only. Any question about this?

Grade 8: 20 Students, Period 3

Teacher: The next characteristic of living things that we discussed was growth. Let's go through it quickly. What are the two main kinds of growth that take place in the body and the cells? Let's go through it quickly. Body and cells — one?

Student: [inaudible]

Teacher: O.K. Cells grow larger. Another type of cells divide. What do you call that?

Peter: Mitosis.

Teacher: "My toes is" cold on a day like this. What do we call mitosis that has gone out of control?

Student: Cancer.

Teacher: All right. What are the three things that mitosis enables to happen within the organism? Three things that mitosis enables an organism – sorry – three things that can happen because of mitosis. [Pause; no response.] Oh! Sorry about that — don't you remember?

Student: [inaudible]

Teacher: O.K. That's one of them.

Student: . . . replaces cells. . . .

Teacher: As a result of this, it replaces worn-out cells — blood cells. It can also replace — what was the first word you used?

Student: Damaged cells.

Teacher: Damaged cells, all right. Like we have when we cut ourselves; and one more? It's going on inside of you — should be a permanent need. Our friend at the back of the room? Yes?

Student: Growth.

Teacher: Growth — O.K. — growth — all right — any questions about those two subunits? Today we'll talk about reproduction in organisms. Despite your concern, what does reproduction mean? Shirley?

Student: [inaudible]

Teacher: Yes! Making a little one like yourself, and it can be done in two different ways.

In these lessons on reproduction Mr. Swift has concentrated on important definitions. These definitions the students are expected to copy into their notebooks. Definitions of "sexual" and "asexual" reproduction are there as well as definitions of "budding" and "fission." During the lesson, Mr. Swift goes over the way these words are to be understood, he ensures that the terminology of the guideline is presented and he follows the sequence of presentation laid down there. Students are given mnemonics to help them remember words like "fission" and "mitosis."

In a later lesson, still from the unit on "Characteristics of Living Things," students were given back their monthly work on "Science Happenings" with completed evaluation sheets; the students discussed their grades with Mr. Swift. He asked the students if they had reviewed their notes for the lesson, and he reviewed the terms "autotroph" and "heterotroph" with them, as well as "ingestion" and "digestion." These terms are stressed in the guideline. Following the recitation, Mr. Swift reviewed with the class the steps that the students should use when writing up a formal lab report. Here, Mr. Swift discussed work associated with the local units the class works on in tandem with the ministry units. Rather than stress words and their definitions, the emphasis in the local units is on procedures and their logic rather than on words and their definitions. Mr. Swift said that the students would need to know how to do the procedures for the "Science Fair." He handed out a sheet which listed seven steps in reporting on an experiment, and gave a brief commentary on the nature of controlled experimentation. The following is an excerpt from his presentation on experimental control:

> "The method – before we go into the method, I want to skip to below the double line two-thirds down the page – 'controlled experimentation.' I've tried to put this in as few words as possible, while still trying to make sense. Sometimes it is advisable to have a control in the experiment. The control portion of the experiment differs from the experiment proper (that's the experiment itself) in only one condition or variable. We vary only one thing. We change only one thing. The control is used as a comparison with the experiment proper; for example: 'Does fertilizer affect the growth of plants?' To one group of plants, the experimental group, I add fertilizer and water. To the control group, I do the very same thing. I add exactly the same amount of water, but no fertilizer to identical beanplants. . . . Why? To keep all other conditions the same – conditions like temperature, the amount of light, amount of humidity, and so on. So I have a control group and an experimental group, because you see, if we didn't have the control group, then maybe you'd say, 'Maybe those bean plants would have done that anyway?' I couldn't argue with you. Maybe they would have done the same; I can't argue with that at all. That's why it's good to have control in an experiment. Last year, in grade 6, we didn't talk much

about control. This year, I expect you to know much more about it. Are there questions about control in an experiment?"

Commentary

In these comments to the class, Mr. Swift emphasizes the methods of experimentation. These methods, as they are listed on the sheet he gave out, are to be used in preparing entries to the "Science Fair," which is one of the six units of the year that the school is to complete. Parents are asked to come to the fair, and prizes are awarded to students in grades 7 and 8. For the grade 6 fair, students are given comments by the judges using a form designed by Mr. Swift. These comments are slanted to provide the student with a positive but critical response. I served as a judge for the grade 6 fair. The gym was full of displays, and the students I talked to all had interesting stories to tell; they seemed enthusiastic and attentive to how they did their projects. The fair appears to have provided a way of doing something extra beyond the material of the guidelines, and for which class time is not available. The fair might be seen as a contrast to the work of covering the syllabus prescribed by the guidelines. The fair involves *doing* science rather than learning the *words* of science, a chance to investigate something in depth using out-of-class time rather than the precious time that has to be devoted to the syllabus.

In the contrast between the lesson from the unit on the "Characteristics of Living Things" and the one on experimental procedures for the "Science Fair" we see the different strands of Mr. Swift's work that he has spoken of. "Characteristics of Living Things" has to be done in the prescribed way. The guideline urges that attention be paid to the naming of the parts, to the words and to science as a body of facts with a specialized vocabulary. The procedures, directed as they are to doing something — getting ready for the fair — emphasize the unpredictable activity rather than memory.

If we think back to what Mr. Swift hopes to accomplish by his science teaching, we can see how the two strands of activity are related to their purposes. Mr. Swift has stressed the importance of the work students do as preparation for high school and beyond. What they do and how they do it get them ready to handle later science work; the work mandated by the guidelines can be seen to serve this function. The "Fair" and "Happenings" units have a more personal context — to help students see for themselves how science is, for example, part of the news and part of what might be a hobby for them. These units provide a more relaxed view of the subject.

It appears that Mr. Swift has attempted to resolve the dilemmas that stem from the pressures of time engendered by the guidelines by incorporating "Science Fair" and "Science Happenings" into his program. These local units allow the students to pursue an almost parallel curriculum, controlled by general procedures of his making, but open to individual selection of material and treatment. These units contrast with ones that aim at uniformity and an assured common core of knowledge. Because the local units do not make major demands on class time, they can be run without undermining the coverage of the material that must be accounted for. The classroom curriculum stresses the subject itself, conceived as a body of knowledge, while in the parallel curriculum, the fair stresses the subject as a *method* of inquiry, and "Happenings" stresses the larger social order outside the classroom.

As we have seen, Mr. Swift makes it clear he values the idea that science work in school should have some connection to the outside life of students, and he is able to pursue that goal, it seems, while at the same time making sure that the core curriculum specified in the guideline is dealt with. It may be the case that the way in which the core units of the guideline are set out creates for him a view of the subject as a body of facts to be transmitted. The emphasis on mandatory units, mandatory topics and required terminology may carry such a message. The guideline seems to say: "Here is how the subject is to be carved up; these are the key pieces; here is how long they take; here is what to stress; here is what you should get across." The organization of the content material says something about the way science is thought to function in the classroom by those who write guidelines. The organization of the science curriculum in the guidelines may reflect how teachers have accommodated to the realities of teaching science in the senior grades of the public school. Material that may be supposed to have received wide approval and that is capable of being taught authoritatively within the time constraints of the timetable is mandated. Ambiguities associated with teaching the subject are reduced, because the teacher is not left to decide what material to teach, and the units that are mandated are presented so as to emphasize their authoritative status through the use of a required vocabulary and mandated topics. The stress on classification, on definition and on the vocabulary encourages a view of the subject as a "rhetoric of conclusions," and, perhaps, gives support to teachers unsure of their knowledge of the subject. The situation many grade 7 and grade 8 teachers find themselves in is ameliorated by the prescriptions supplied in the guideline. Is it an accident that Mr. Swift found the guidelines a "godsend"?

Certain educational values are also built into the very structuring of the material itself. Perhaps one important value is that the students may come to see themselves as having no responsibility for the knowledge they hold, because the knowledge is being passed on as text to be learned, rather than as lessons in, for example, the nature of scientific knowledge. Seen as instruments of communication, the guidelines convey meta-lessons to teachers as well, such as lessons about what science it is important to teach, about how the teacher should stand vis-à-vis knowledge and students, about how time should be used and about the nature of interactions in the classroom. For Mr. Swift, the practical consequences of the guideline structure have been a mixed blessing. The guideline makes it clear what he is expected to teach. However, messages about how he is to teach, implicit in the nature of the document, may not encourage Mr. Swift to capitalize on his strengths as a teacher, on his and his students' interests and on the educational possibilities science holds for his students. On the other hand, in his view, the guideline has helped him resolve a number of important problems that confront him at the grade 7 and 8 levels. Clearly, the function of the guideline is complex.

What Mr. Swift has done, it seems, is to create a program that resolves some of the remaining tensions. The syllabus is covered (that is, the body of information it represents is transmitted to the students), some of the social context of science is captured in the "Science Happenings," and through their "Science Fair" work students get to experience some of the excitement of science as a process. Emerging from our conversations is the possibility that an important activity for inservice education may be for teachers to consider what dilemmas they *do* cope with, how they cope with them, and what their views are about prevailing resolutions in the light of what they hope might be achieved through science education. Through conversations with colleagues and others, teachers might be able to articulate these experiences for themselves and others.

This concludes our study of Mr. Swift's science teaching at the level of grades 7 and 8. As our attention turns from Mr. Swift to Mr. Clark, and later to Mrs. Macdonald, we shift from a teacher who teaches science in all his classes to two teachers who work with science for only a small fraction of their total teaching time. In one sense, then, the following portraits are incomplete in a way in which Mr. Swift's was not. Much of the work of Mr. Clark and Mrs. Macdonald does not come under our direct scrutiny. Nevertheless, distinct features of their overall teaching philosophies do emerge, along with some of the unique features of teaching science to younger children.

Science in the Junior Division

Mr. Clark is in his twenty-first year of teaching, and his sixth year at Trillium Elementary School. This year, his class is a "straight" grade 5, without the addition of a small number of grade 4 or grade 6 pupils to create a "split" class, as in recent years. There are almost twice as many girls as boys in this class of 30 children. The classroom is pleasant, with a large map of the world filling the bulletin board on one wall. Across the top of the blackboard at the front of the room are excellent drawings of airplanes. Examples of recent written work are also posted, and noticed by the children. Mr. Clark has no desire to work in an administrative capacity in the school, for he sees himself as belonging in the classroom. Nevertheless, Mr. Clark is attentive to administrative arrangements within the school. He has worked to ensure that "free" time during the teaching day is divided as evenly as possible among all the teachers in the school. He believes that any surplus of free time should go to teachers in the primary division, grades 1 to 3.

Mr. Clark quickly replied, "No, not at all," to my asking whether science is "pushed" at Trillium Elementary School. He says this realistically, not negatively, and he sees two factors related to his conclusion. One is the fact that Trillium Elementary School does have a "Science Room" with facilities and equipment uniquely suited to the teaching of science. However, the science room is largely unavailable to any but the grade 7 and 8 students. Mr. Clark recounts that attempts to take his own students into the science room were met by responses indicating that this would be inconvenient for the people regularly using the room and that area of the school. The second factor derives from the fact that no one in the school is designated as "the science teacher," with responsibility for supporting science in every classroom. This role could fall to Mr. Swift, as teacher of science to grades 7 and 8, but Mr. Swift has not adopted such a stance. Mr. Clark describes Trillium Elementary School as very traditional and very comfortable, and one characteristic this implies is that a teacher does not move outside his or her present role. Mr. Clark did make an effort to have the entire school see the room in question as a science room for the school, without interfering with its use by grades 7 and 8, but no one else responded to the opportunity, and the idea died. Mr. Clark does all his inschool science teaching in his own classroom.

Mr. Clark expresses a personal view that most science teaching is and should be incidental, with everything depending on proper timing. For example, when the space shuttle was first launched, he devoted the entire day to that topic and related matters, building on children's keen interest. When water pollution became a topic in the local newspaper over a period of several weeks, he made that his topic for science. Mr. Clark also stressed his personal view that on complex and controversial topics a teacher must remain "completely unbiased," working strenuously and continuously to avoid being on either side of a value question. For example, when explaining the "bad" features of water pollution, he also points out that, when wastes already exist, something has to be done and compromises made. Real problems cannot be ignored. Mr. Clark sees his role with grade 5 children as one of giving them the facts and letting them decide for themselves on matters of controversy. This general posture is one that Mr. Clark maintains throughout social and environmental studies, recognizing that the line dividing the two is sometimes blurred.

Logical thinking and organization are two of the major themes of Mr. Clark's work with his grade 5 class. He hopes that, by the end of the year, most children will be better able to organize their thoughts, to sort out what is important and to recognize what to accept and when to listen. At this age they already know many facts, and he strives to arouse their curiosity, to lead them to new questions and to have them apply what they already know. For example, he hopes to get away from statements like "That's a robin," and move on to questions like "How and why can a robin fly?"

Experiments on "Air"

My observations of science teaching by Mr. Clark took place during a unit on air. Science is taught within the social and environmental studies (SES) periods which are scheduled into the school's six-day cycle. A total of 300 minutes is allocated to SES over each six-day cycle, for a daily average of 50 minutes. Every other day there is an SES allocation of 60 minutes, between afternoon recess and the end of the school day. It was agreed that these periods were the most suitable for observation.

As the children returned to the classroom from afternoon recess, they immediately noticed the "apparatus" hanging from the ceiling at the front of the room, directly in front of the chalkboard. Two tetherballs were suspended by string from opposite ends of a metre stick, and the stick itself was supported by a piece of string at its midpoint. A piece of plasticine at one end of the metre stick served to balance the stick in a horizontal position.

Science teachers will quickly recognize that this apparatus is intended to provide data relevant to the question of whether air has mass. This fact was also readily apparent to the children, but the dialogue that occurred in this introductory phase of the activity illustrates something of the nature of discussion of science topics at the grade 5 level:

Mr. Clark: What on each side gives it the mass?
Student: Air.
Mr. Clark: What else must balance?
Student: The stick across. . . . How much the string is. . .
Mr. Clark: There's something else you forgot: the weight, the mass of. . .
Student: The weight of the tetherball.
Mr. Clark: And the mass of the plasticine.

At this point, Mr. Clark pointed out that he had also taped an inflating needle to each ball, because a needle must be inserted to permit air to escape from one ball. He then used another metre stick to demonstrate visibly the effect on the stick of changing the mass attached to either end. Interestingly, as the discussion proceeded, Mr. Clark alternated between the terms "weight" and "mass," on some occasions correcting "weight" to "mass." The children seemed to use the term "weight."

Mr. Clark: If I were to remove the air from one, what would happen?
Students: It'll go off balance.
Mr. Clark: Which way would it go? Think about it for a minute.
Students: [They indicate their personal opinions.]

Mr. Clark: Most of you seem to agree it will go up. What would that mean, or prove?

Students: Air has weight.

Mr. Clark wrote "Air has weight" on the board and then inserted a needle to permit air to escape from one of the tetherballs. No obvious change could be observed in the position of the metre stick, and the children concluded that its position was unchanged.

Mr. Clark: Would you agree that air has weight?

Students: Yes.

Mr. Clark: But it's a very small weight.

This discussion has taken about 15 minutes. For the next 20 minutes, the children perform a similar experiment after an explanation by Mr. Clark. By inserting a pin through a plastic straw and into the end of a ruler held to the desk by a book, the children could attach an inflated balloon to one end of the straw and balance the mass of the balloon with a tiny piece of plasticine at the other end of the straw. They were then asked to observe what happened to the position of the straw when they used a pin to puncture the balloon, inserting the pin near the neck of the balloon to avoid having the balloon break into pieces. With great enthusiasm, and an impressive degree of orderliness, the children proceeded to create every imaginable variation on the general theme. I was called upon to tie knots in balloons and to insert pins into the ends of rulers; I was also called upon to assist in interpreting the widely varying results. Several pairs of children managed to create a slow leak in a balloon, enabling them to see the straw tilt more and more as the balloon shrank in size.

Twenty minutes after the experiments began, the children were busy cleaning up, and the room soon looked just as it had before. After a brief discussion of the results and a short demonstration by Mr. Clark, the children were asked to take out their SES notebooks and begin their write-up. The following material was written on the board for the children to copy, before drawing a diagram to show the apparatus used.

Activity IV

Purpose: To see if air has weight.

Apparatus:

The children were offered a choice of drawing the tetherballs or the soda-straw balance; roughly half the students chose one option, and half chose the other. The class worked quietly until the bell rang; normal end-of-school activities were followed by dismissal.

A few days later, another lesson in the same unit on "Air" again presented the pattern of simple demonstrations accompanied by discussion, questions to the children and written work by the children in their exercise books. During the lesson, I was impressed by the preparation time required to ensure that demonstrations could and would work. Science demonstrations also require a confidence that things will work, and a readiness to go looking for extra equipment.

"Let's get around the table as best we can and make sure everyone can see. This is an ordinary stick, and this is an ordinary piece of paper [perhaps 25 by 40 cm.], and all I'm going to do is put it on the table and try to flatten out all the air underneath it. Then I'll take this hammer and. . . . [Mr. Clark strikes a metre stick, which rests on the table beneath the paper with a short piece visible beyond the edge of the table.] That didn't work out as I thought it should. Let's try again. Watch your eye, right? This time, hopefully, it's going to lie a bit flatter. . . [he tries again]. No it didn't. I've got some hard wood, it's bouncing on me. There, it worked.

"Now what in the world could be holding that down like that? I mean it's just paper, it doesn't weigh very much. Why is it that I can just break it off like that? What is holding it up?"

A student replies:

"The air pressure?"

Mr. Clark then had the children return to their desks. After showing the progress made by another demonstration, he asked them to enter the breaking-stick demonstration in their exercise books while they waited.

Learning Scientific Terms and Concepts

An interesting illustration of the way Mr. Clark deals with terminology special to science emerged as students copied the "purpose" of the next activity they would observe and write up. On the board, Mr. Clark wrote: "Purpose: To discover the effects of heating and cooling on a given volume of air." When one child asked him the meaning of the word "given," Mr. Clark responded with the following comment:

"You people all sit down, and if everyone could put their pens and pencils down for a minute we'll look at the second part so you can see what is happening. I've mentioned this before, Scott. I'm going to continue using words that are often used in science, such as 'given,' which simply means the amount of air you have. In this case, it is just the amount of air that is here in the bottle. You can't change that, can you? Once I put the top on you can't add air or take it away. That's why we mean 'given.' And instead of 'amount,' I'm using 'volume.' "

To complete the hour-long science lesson, Mr. Clark turned to a demonstration that is a favourite of virtually all science teachers — the "collapsing can." A small amount of water is boiled for several minutes in a large metal can; then it is removed from the heat and sealed. Soon after, the can begins to collapse, as the steam condenses to water and the pressure inside becomes much lower than that of the air pressure outside the can. Mr. Clark wrote the following purpose on the board: "To discover the effect of atmospheric pressure on a closed low pressure system." The discussion included the following dialogue:

Mr. Clark: I've heated it up, the air has expanded, some of the air has come out because it has expanded, the water vapour in here has pushed more air out. I'm going to seal it off and the air is going to try to get back in, but it can't get back in because the seal is in the way. It is a closed container. We sometimes give that a different name. Right now there is air trying to push on us. You know pressure when you dive. . . but there is a name for it. We don't just say the air around here, we call it. . .

Student: Atmosphere.

Mr. Clark: Usually we call it what kind of pressure?. . . . Atmospheric pressure. All that really means is that the air is pushing down from the atmosphere.

After referring to a diagram showing how air pressure varies (high and low) in the atmosphere surrounding the earth, Mr. Clark proceeded with the demonstration.

Mr. Clark: Right. I've got a wet rag here so I can hold [the can] steady. I put the top on. I hope I've got a top that fits well. I seal it up so that no more air can get inside. . . . Look at that poor old can. [As the can collapses more and more, the children make excited comments.] So that is just air pressure. So do you think air pressure can do work? It's hard to get a hold of cans like this one. Can someone fix this one for me? [There are no volunteers.] We've had lots of new words today – "high air pressure," "low air pressure," "closed container"; we've got "atmospheric pressure," which simply means the air all around us. I don't think anyone in this room will doubt that air pressure can do a lot of work.

Mr. Clark then left the room briefly and returned with a can identical to the one that had just collapsed. Several boys accepted the challenge of trying to crush the new can as much as the first can was crushed by air pressure. With considerable effort, they did manage to make substantial inroads into the new can, and this activity gave emphasis to the claim that "air pressure can do a lot of work."

Evaluation in Science/SES

In discussion after the children had left for the day, I inquired about testing that might be used to judge how students had responded to a unit in science. Mr. Clark's reply is indicative of the status of science in his view:

> "I usually find that whenever I give a test, it's almost a hundred per cent. In other words, when I give a test, what I expect them to know, they know pretty well. A hundred per cent of them know it

all. I'm not too concerned about the end test result. But if I do do something, it is usually something like that. [Mr. Clark refers to a two-page test with statements about Australia, requiring students to give the comparable facts about Canada.] It's a comparison where I might give them facts about one country and ask them to regurgitate on another. For example, I would want them to know the provinces. The only thing I test ability in is mathematics and English. You can tell — if you look in my SES book, there are only a couple of marks. That's SES, so there are only two things that I have tested. Math is a mechanical thing where one thing builds on another, and if they don't know this fact, they sure won't get the next one. In science it's different, because they learn most of it by osmosis anyway. Each year they are going to pick up a little bit more."

The reply given by Mr. Clark when I asked whether he evaluated the students' notebooks in science is indicative of one of the ways in which social realities can influence work at the grade 5 level. Mr. Clark also acknowledges the pressure that can come from "theory" about how education should proceed:

"I do evaluate their notebooks. You know, how they set it up. I tell them that that is just preparation for their future jobs, so to speak. I know you're not supposed to do that in education, but let's face it, when you get out on a job you're going to be evaluated. They're going to look at your notes, your record-keeping. He may judge you on that as much as on your performance."

Commentary

A dominant impression from these lessons on air pressure is the confidence and skill that Mr. Clark has developed in the presentation of a variety of phenomena relevant to a basic, yet challenging, scientific concept. Mr. Clark assembled equipment almost "on the run," yet everything proceeded smoothly, and he knew just where to look for additional materials. Starting with no more than a combination sink-and-drinking-fountain at the back of the room, Mr. Clark's teaching of science combines self-reliance with the confidence of a number of years of experience.

Mr. Clark's comment that "they learn most of it by osmosis anyway" reflects the reality that our culture is permeated with products made possible by science and with mass-media presentations of science content and science-related issues. Children in grade 5 have ready access to these aspects of their culture, but have not yet reached the stage at which science becomes one of five or six "subjects." Language arts, mathematics and the basic skills of all schoolwork are still fundamental. Only a few science topics are dealt with in the course of any one year. Some of the differences between the pre-highschool context of Mr.

Swift's science teaching and the grade 5 context of Mr. Clark's teaching become more sharply defined in the setting in which Mrs. Macdonald teaches science.

Science in the Primary Division

Over the past 11 years at Trillium Elementary School Mrs. Macdonald has taught at various grade levels, but most of her time has been spent between grades 3 and 6. During the same period she has also completed her BA degree through part-time studies at Queen's University, which is located within commuting distance of her home and the school. This year Mrs. Macdonald teaches grade 3, which falls within the primary division — kindergarten to grade 3.

Mrs. Macdonald talks easily about her work, and a listener is quickly made aware that having children work in a variety of group arrangements for at least part of each day is an important part of her teaching philosophy. Basically, Mrs. Macdonald approaches the teaching of science with a sense of confidence. Within her overall program, she integrates subject areas whenever possible, and "integrating" is the major way in which she teaches science; she finds that science integrates well with mathematics and social studies.

These basic features of Mrs. Macdonald's philosophy were apparent in my first observation of her teaching. Social and environmental studies is scheduled in the afternoon, and the lesson began with an activity for the entire class. A large map showing the boundaries of the provinces and major lakes of Canada was used to elicit first the names of all the provinces and then the children's responses to questions of the form, "What province is immediately west [or east] of Alberta?" Several competitions between groups were arranged, and then "time trials" were held to see how many children could, within a three-minute period, point to and properly name the five Great Lakes. This 15-minute period was followed by a 10-minute viewing of part of a filmstrip (of US origin) on "The Far North." As children took turns reading captions, Mrs. Macdonald asked questions such as "What did you notice?" and also maintained order by statements such as "I don't have people calling out." For the next 30 minutes, children were arranged in groups and directed to centres within the room. At each centre, the children found directions for working with the materials provided for them. The directions at Centre 2, below, illustrate Mrs. Macdonald's approach and her attention to posing different levels of questions:

FOR YOUR EYES ONLY!

1. Choose one envelope.
2. Study its contents carefully and report your findings on a sheet from the box.
3. Be sure to return contents to the envelope without others seeing.

One child found a picture of an unusual vehicle and the following questions:

A. What are you looking at?
B. What is different about this vehicle?
C. What time of year is it in the picture?
D. What clues help you decide?
E. Draw a sketch of the vehicle.

At this and some of the other centres, the children went ahead with their work without much difficulty. Yet any observer would have noticed that six children were receiving the greater portion of Mrs. Macdonald's attention, in part because they had not mastered the skills of working steadily and independently.

The preceding account of one day's SES period, between lunch and afternoon recess, provides an introduction to Mrs. Macdonald's teaching situation, including its many challenges and her overall approach to teaching science. When asked to describe what had happened in the science (SES) area of the curriculum in the first part of the school year, Mrs. Macdonald replied very straightforwardly, "Not as much as I'd like." Short units on plants and "the universe" preceded discussion of living things in general, eventually resulting in a "decision" to study mammals in greater detail. This investigation led to a focus on the tundra area of the Canadian North, because Canada is an SES focus in grade 3 and because the animals of the tundra tend to be mammals. Mrs. Macdonald's teaching philosophy and experience are evident in her further explanation, that the mammals of the tundra are not those of the children's everyday experience. The differences would provide a basis for comparison, and the children would not "get hung up doing a unit on the cat or the dog."

When we discussed the units recommended by her board of education for grade 3, Mrs. Macdonald explained that quite a bit of material is provided for teachers, but more to be used as a set of starting points than to be used as printed. For example, she expects to integrate the content of the two physical science units designated for grade 3 into the unit on the tundra and Canadian North. Mrs. Macdonald's ability to practise the integration she believes in suggests that she is fairly comfortable with science topics. She explained that she was offered a position teaching science at the grade 8 level in another county when she completed her preservice teacher education, but she decided against that position in favour of working nearer home. Mrs. Macdonald believes that she does not include enough science in her program, that she could do more and that science is not included to an adequate degree in the elementary grades, particularly kindergarten to grade 3. In Mrs. Macdonald's view, her county has worked very hard to incorporate the concepts of *The Formative Years* (the official Ontario curriculum document for kindergarten to grade 6) into its school programs. We could only speculate as to why separate science units have been developed, rather than units that integrate social and environmental studies.

Integration in teaching at the elementary level is obviously facilitated by Mrs. Macdonald's ability to relate content areas to each other. She rarely uses a curriculum document as it is printed. When teaching grade 4, several years ago, she never used the official unit on "Water." Instead, Mrs. Macdonald "used 'Water' as the vehicle for teaching the whole SES program." After studying the local water system, the students studied reclaimed lands in Europe. The Nile River system in Egypt served as an ancient community, and the formation of Hawaii by volcanic action provided water-related study of a "new-found land." "One could almost go around the world using 'Water.' "

Related features of Mrs. Macdonald's teaching are her sensitivity to children's interests and her responsiveness to items children bring to school. This year the classroom has one fish tank, which has most recently served to demonstrate the "pollution" that results from overfeeding the fish. In a previous year, when the children were "super keen" about the live fish, four tanks were used, many species were bred successfully and these activities served as a focal point for work in family studies. (All such activities are both demanding and risky; one winter weekend the heat failed in the school and only the fish in the largest tank survived.) Plants line the window sills in Mrs. Macdonald's classroom, adding interest but also providing a ready source of material for studying plant propagation. Mrs. Macdonald attempts to "facilitate" unexpected events that display teaching potential. When a boy brought a young snake to school, Mrs. Macdonald had time to prepare some worksheets for the children before they returned from lunch. "You just throw out your afternoon's work and go at it in a different way." The children practised measurement, estimation and looking for detail; then they drew the snake twice, in an attempt to get the most accurate colours.

Mrs. Macdonald's work in grade 3 shows how themes can be developed and how aspects of science can be integrated with other subjects. She tries to build on children's interests, but she balances what they "want" to do against her own sense of her responsibilities as a teacher of young children. Thus when 75 per cent of the children declared an interest in mammals, their topic became "mammals of the tundra," to ensure that the children would be challenged by the unfamiliar. Many children are eager to have a "pet day" when they can bring their pets to school, but there are six asthmatic children in the class, so pet day will wait until warmer weather when children and pets can meet outside. The presence in the class of a significant number of children who require almost constant "surveillance" is an obvious constraint on arrangements of children for working purposes, and Mrs. Macdonald's customary use of groups has been delayed and reduced this year. To explore the possibility of moving one child to a special class in another school, Mrs. Macdonald's principal spent two days in the classroom to observe the child. The principal's presence did not appear to disturb Mrs. Macdonald, but it was yet one more element in the complex scenario she orchestrates each and every day. The child in question was moved to another school, but management of a significant number of "challenging" children will remain one of the major demands on Mrs. Macdonald's teaching energies throughout the school year. "Some years are like that," says Mrs. Macdonald. In fact, the child who went to another school will continue to visit Mrs. Macdonald on a weekly basis, to facilitate the child's eventual return to the school.

After completing the unit on mammals of the Canadian tundra, Mrs. Macdonald's science program moved into a period of work on "individual projects," in which each child uses library materials to prepare a report on a particular species of animal. This is, in fact, the introduction of the grade 3 children to the work of library research and report preparation that will continue and increase at subsequent grade levels. Each child received six pages of material to guide the development of the individual project, and it is informative to note the specific structure provided in this science project:

Page 1: List three animals you might like to investigate and do a project about.

Tell me where you would go to get information about your choice.

Write questions that you would ask about one of your choices.

[Space is provided for nine questions.]

Page 1 provides the basis for Mrs. Macdonald's individual discussion with a child, to determine the particular animal to be studied. Mrs. Macdonald relies here on her knowledge of material available in the school library, and she gives each child page 2 and explains how it is to be used to record visits to the library and work accomplished there.

Page 3: My project is about ______________________ .

Here is my drawing of ______________________ .

[The remainder of the page is used for the child's drawing.]

Page 4: The ______________________________ belong to
the ______________________________ family in
the ______________________________ Kingdom.
We know this because the ____________________ has:
[Eight lines are provided.]

Here is a picture to prove the ____________________
is ______________________________ .

[Space is provided for picture.]

Page 5: Where do ____________________ live in the world?
[Five lines are provided.]

On the map of the world I have shaded in the area(s) that
______________________________ live in.
I have used ________________ to show their location.

What is the country that they live in like?

Describe the type of land formations and vegetation it likes for its home area.

[Six lines are provided.]

Page 6: [Bears the title "Bibliography — Books I Used." Two columns are marked off vertically, one headed "Author or Company," and the other headed "Title of Book or Magazine."]

During this period of individual projects in science, one class included the viewing of part of a filmstrip (produced in the US in 1962) on the classification of animals. The filmstrip credits Aristotle with the first important step in classification, moves quickly through several possible classification schemes (e.g., useful-harmful) and then introduces Linnaeus as the designer of our present system, based on structural similarities. In the phylum Chordata, five classes of the subphylum Vertebrates are introduced: Fish, Amphibia, Reptiles, Birds and Mammals. One child reads the captions very competently, and Mrs. Macdonald poses questions about the content. Filmstrips such as this one are an important resource for teachers, yet I was struck by the abstract and routine treatment of the topic.

This brief glimpse of a teaching approach and associated classroom events in the teaching of science at the grade 3 level is hardly "typical," but it is indicative of some of the issues surrounding the teaching of science in the elementary grades. Mrs. Macdonald is having a difficult year, in terms of managing the group of children in her class. She approaches her work in science with considerable confidence, and she appears to enjoy the challenge of content integration, particularly within social and environmental studies. Somehow Mrs. Macdonald seems to know what each child is doing. She follows each individual closely, and at times groups children for individual work to enable them to practise their social skills.

This year, Mrs. Macdonald has eight parent volunteers who come for half or all of a morning or afternoon, once a week. The volunteers tend to work with one child who has a particular need for remedial work, and Mrs. Macdonald sees the volunteers as making a substantial contribution. Mrs. Macdonald shares Mr. Clark's view that Trillium Elementary School is basically a rather "conservative" school. This year she is adjusting to the absence of a teacher (now transferred to another school) who previously taught in a nearby classroom and served as a close colleague and "sounding board" for new ideas about teaching. Opportunities for dialogue about teaching seem rare in the day-to-day work of many teachers. Mrs. Macdonald clearly finds dialogue very valuable, and she actively searches for it. She traces many of her ideas to inservice workshops within her own board of education and to meetings in Toronto and elsewhere in Ontario under the auspices of the federation to which she belongs.

Commentary

In the primary division, more so than in other divisions, the teaching of science appears to be much more closely related to children's natural interests in particular aspects of the world around them. The formal language of experimentation has not yet become necessary, for reading and writing skills are still developing, along with the skills of group interaction that school requires. Themes are more prominent than subjects, and Mrs. Macdonald's skills of content integration illustrate the potential and the convenience of a thematic approach to learning. Like Mr. Clark, Mrs. Macdonald works almost exclusively in one room with one group of children and without a stock of formal science equipment. Again, teaching science requires self-reliance, and confidence seems to come not so much from the support of other colleagues in the school as from years of experience in which advantage is taken of out-of-school opportunities to explore ways of teaching science-related content.

Afterword

Teaching science in the primary and junior divisions contrasts sharply with that in the intermediate division. As Mr. Swift stresses, he could not run the program he does if he had responsibility for other subjects. Only by being able to concentrate on one subject is he able to cover the amount of work prescribed by the Ministry of Education. If he were a home-room teacher, he reckons he could not cover the material for which he is responsible.

Science as a defined subject does not exist in the primary and junior divisions. For Mr. Clark and Mrs. Macdonald, the pressures of covering mandated content do not exist. Science units for use in kindergarten to grade 6, however, have been developed by writing teams sponsored by the board of education. For example, in grade 3, the physical science units are "Heat" and "Astronomy"; in grade 5, the units are "Air" and "Crystals." These units are intended to be used during the social and environmental studies portions of the daily timetable. Although the teacher's guide to the set of units stresses integration with language arts and mathematics, certain science content and inquiry skills are intended to be developed in a systematic way through the primary and junior divisions. These units have been made available to all primary and junior teachers at Trillium.

The ministry guideline (*The Formative Years*) for kindergarten to grade 6 does not prescribe any particular content to be dealt with in science, and there do not seem to be any pressures from the board of education to follow the local units in the way that Mr. Swift feels under pressure to follow the guideline for intermediate science. Here we see an important difference in the work contexts of teachers in different divisions within one school.

While Mr. Swift has sought to integrate the work prescribed by the guideline with current events and "Science Fair" activity, Mrs. Macdonald and Mr. Clark are faced with the task of integrating science with other elements of the curriculum. For them, integration is the official policy of the ministry; in Mr. Swift's case, it is part of his own desire to create interest in science and to overcome what he sees as fear of the subject engendered by insufficient contact with science in the earlier grades. He is critical of the integration of science with other subjects in the earlier grades, and he thinks it is the lack of attention to science there that creates for him the task of overcoming fear of the subject.

For Mrs. Macdonald and Mr. Clark, "science" content is used as opportunities arise and as children express interest in various topics and with a view to developing curiosity and the ability to organize and think clearly about information. The efforts of the curriculum writing team that developed the primary and junior science units to create local guides for science that approach the level of systematic treatment that exists for mathematics and language arts do not seem to fit with the view that science can be taught as occasions arise and according to the interests of the children. Perhaps quite different views about the role of science are at work here. Given these different perceptions of how science should function in the elementary school, groups intending to develop curricula should appreciate how the teachers they wish to influence make sense of their work, so that all involved might collaborate more effectively in making the most of what science has to offer to the elementary school curriculum.

IV. McBride Triptych: Science Teaching in a Junior High School

Brent Kilbourn

McBride Junior High School has a total student body of about 570 in grades 7, 8 and 9. The building itself is less than five years old and is a pleasant, if architecturally conservative, structure. The facilities at the school, while not extravagant, would be considered very adequate by most standards. The school serves an urban community that is racially mixed but predominantly Anglo-Saxon. The socioeconomic status of local residents runs the continuum from low income to high income/professional, but the bulk of the community would probably be best described as stable and working-class. However, in spite of the "stability" of the community, the principal estimates that as many as 60 per cent of the students come from single-parent homes.

The science department is located in three adjacent rooms, with one room for each of the three science teachers. Students in grades 7 and 8 have science on four out of six days, on a rotating schedule, while grade 9 students meet every day. The periods are 40 minutes long. The classrooms have been designed for science teaching and are relatively well-equipped – no teacher found a lack of science equipment and supplies to be a serious impediment to his or her teaching. The classrooms have a perimeter-lab-counter design with water, gas and electrical outlets at each station.

Each of the three science teachers at McBride has more than 10 years of teaching experience. The grade 7 and 8 teachers are essentially "new" to science teaching this year, and the grade 9 teacher is the only one of the three with a formal academic and teacher-training background in science. The three are good friends and work well together; they are gregarious and very much involved with the social aspects of the school. From my experience it would be fair to say that their demeanour is "upbeat" and cheerful, both towards students and other staff members.

In this case-study report, I attempt to paint a picture of what science teaching is like, within a limited time frame, at McBride. I tried to avoid anticipating what I would find, in keeping with the naturalistic approach of the study, and to allow the salient features to emerge from the data. It is only fair to point out some of the more general concerns that oriented the research. I have been concerned with addressing the intellectual or substantive aspect of science teaching (e.g., content and process of science) as well as those aspects that cluster around the term "socialization" (e.g., management and control, classroom climate and the nature of teacher-student interactions). I have been concerned to address these in such a way as to indicate what teachers *say* they are doing and to indicate what they *are* doing. That is, I have attempted to form images of how teachers' intentions are manifested in their teaching.

Furthermore, I have attempted to provide an account that will allow a reader to interpret science teaching from the teacher's point of view and from the student's point of view. The former has been captured in the quotations from teachers during interviews. To grasp the student's point of view, however, the reader will have to make inferences from the structure and substance of the accounts themselves. (My informal talks with individual students served primarily as a triangulating device for my own descriptive impressions; on the whole, students were not questioned concerning their own "feelings" about what was happening.)

With minor variation, each of the three science teachers at McBride is responsible for one grade level. I observed each teacher for approximately one month. During this time I stayed with one class as it worked through a unit of material. Each teacher selected an "advanced" class for observation. All the lessons observed were tape-recorded and most were transcribed. In addition to the sequential observations of a single class, I spent one full day with each teacher and occasionally caught bits and pieces of his or her other classes. In addition to informal discussions with the teachers, I held more formal interviews with them as well. These too were taped and transcribed.

The accounts of each teacher's work were developed in the following way. During each lesson I took notes on salient aspects of the lesson and noted questions I wanted to ask the teacher. These notes, and other information collected at various times, were then used to generate broad topics and questions for the interviews. The information in the transcriptions of the interviews and in the field notes was used to develop the basic structure of each account. I then went back to the transcripts of the lessons to find examples of the major points. In the accounts, all of the quoted material is from the transcriptions of the lessons and interviews. (In some cases, quotations have received minor, nonsubstantive editing to improve readability.)

I have tried to let teachers and students speak for themselves, by quoting from the interviews and lessons as much as possible. The emphasis in the accounts is descriptive rather than interpretive, and the intention is to provide enough data, in context, so that a reader can make his or her own interpretations. Each account is structured on its own terms, which is why the same topics are not always found in each account and why the presentation is somewhat different in each case. The generalizations that I do make are limited to the period of time and to the class in which observations were made.

Grade 7

Steve Henning has taught at McBride Junior High School for the past four years. He teaches grade 7 physical education half-time and, for the first time in four years, also teaches grade 7 science (half-time). His BA degree is in geography, and he has acquired enough credits for a "major" in physical education. His training at the Faculty of Education was in physical education and geography.

Mr. Henning has taught English, history, geography, science, mathematics, typing and physical education. This jack-of-all-trades experience is partly due to historical trends: "We happen to be departmentalized a lot right now. When I first came on, most of the people taught a bit of everything, but it's just turning around." Another factor is that, because of seniority, it is often difficult for a beginning teacher to be given the subject he or she wants (in this case, physical education). "So, I knew that because of the situation I'd just keep plugging along doing whatever they asked me. I didn't do a lot of complaining and I didn't really figure I had an option to anyway."

Although Mr. Henning obviously enjoys teaching science, he said: "If I had a choice, if someone said, 'Do you want geography and phys-ed or do you want all phys-ed?' I'd take all phys-ed or I might take all geography over science." It should also be noted that, training and personal preference aside, teaching a "protected" subject like physical education means more security in a period of declining enrolments and financial cutbacks.* Consequently, if, for example, he had to choose among a variety of inservice workshops, "Because science isn't my chosen field I would rather spend workshops doing phys-ed."

* "Protected" subjects are those that would be taught (and, consequently, would have to be staffed) even if enrolment dropped drastically. Physical education, for example, is a "protected" subject, whereas Latin is not.

In the context of "inservice workshops," Mr. Henning commented on the needs of grade 7 students and the demands on their teacher:

> "I figure that with grade 7 science you're building on the fact that it's not hard to keep a few steps ahead of the kids anyway. Grade 9, I'd definitely have to take more work to do a really good job. But for 7 and 8, I have a good basis in [the subject] anyway, and I've taught 7 and 8 science, so I figure my background would be good enough."

These comments fit with Mr. Henning's view of himself and of grade 7 teachers as generalists: "I figure with grade 7 you should be able to teach just about anything."

The fact that this is the first time in four years that Mr. Henning has taught science, coupled with his view of the teaching demands, means that his planning tends to project two or three days beyond class. He uses guidelines, several texts and previous notes in planning a lesson, but the precise topic for any particular day is largely determined (in the case of this particular unit) by following an "A" student's notebook from the previous year.

Goals

Given the opportunity to talk generally about his goals, Mr. Henning tends to emphasize those concerning socialization. On several occasions he mentioned the importance of developing a sense of responsibility, routine and manners. This view stems from his perception that grade 7 students often seem to have little respect for property or for each other:

> "I figure if the kid has developed some sort of manners and some sort of responsibility and some sort of routine, I've succeeded whether or not he learns any science. I figure if he's done that or has developed some of that partly through my teaching or my influence, I feel like I've done a good job. I really feel that for a lot of these kids that's more beneficial than learning how the conduction of heat works the way it does in water and air, or whatever."

The emphasis on routine and responsibility also relates to the idea that, in this science department, grades 7 and 8 are seen as the training ground for grade 9:

> "The way it's set up here, we follow a similar format with the activity sheets, the group work, and so on, and by the time they get to grade 9, they're all set."

The idea of training for grade 9 is also prominent when Mr. Henning talks about goals specific to science. Two goals appear to dominate his thinking about grade 7 science — learning applications to everyday life and learning the basics for subsequent grades:

> "[For example], even if they can't give me a good definition of conduction, they know they aren't going to touch a steel frying pan. They may forget [it's called conduction], but they'll remember the basic principle behind it, which is just as important, I think. But

that's at the 7 level. At 8 and 9, it gets a little more sophisticated. [For example], setting up an experiment. This is probably the first year they've set one up the way they have, the first time they've gone through that routine. Now when they get to 8 and 9 they've got that, and then they can do other things. . . . I think science is a building process. You can't jump into grade 11 or grade 12 chemistry without some background, grade 9, 10, 11 or whatever. You have to have some of the basics as you get up there."

Teaching

Routine, then, is a feature of both socialization goals and goals in science, and it is not surprising that an observer sees a great deal of routine in the classroom. At this point it is helpful to sketch some of the more relevant details of the class I observed. Of the 17 lesson observations, 12 were spent with the same advanced class. Although the perimeter-lab classroom looks spacious, it is very crowded with 36 students, especially during lab activities. According to Mr. Henning, the large class size is due to at least two interrelated factors. This class incorporates all the students taking instrumental music (who have to be kept together for scheduling purposes); also, the policy of keeping general-level classes smaller in size (20 to 30) pushes up the number of students in advanced classes.

The class was observed through an entire unit on "Heat and Temperature." The class had recently completed a unit on measurement and the metric system, which was preceded by a unit on the characteristics and interdependence of living things. Within the "Heat and Temperature" unit, approximately one 40-minute lesson focussed on each of the following topics, in this order: introduction and film on heat; film on heat and discussion of convection, radiation, conduction; use of the Bunsen burner; activity on different rates of conduction; activity on water convection; demonstration of heat absorption; demonstration of heat loss; activity on bimetallic strip; demonstration of expansion with heated ball and ring; review; test.

During my visits, I became aware of the following general routine during each period of science class. As students enter the class, they are expected to take out their science notebooks and review until Mr. Henning formally begins class. This period of time usually lasts two or three minutes and, as the students are often talking or "messing around," it is frequently a time when Mr. Henning forcefully reminds them that they should be reviewing their notebooks. The notebooks are compiled by each student for each unit and, on the whole, are made up of the activity sheets (which usually include diagrams and answers to questions). The next part of the class is usually devoted to answering questions or reporting observations and conclusions from the "experiment" of the previous day. Then a new activity sheet is handed out, which the students copy. Sometimes the activity sheets are mimeographed and students are given a copy, but usually there is only one class set. The remainder of the lesson is spent with students doing the activity in groups of four or five. The following excerpts from several consecutive lessons illustrate this general pattern and show how, in a few specific instances, Mr. Henning addresses his goals of socialization and science content.

Thursday
Near the end of the class students are given the following activity sheet to copy in their notebooks:

HEAT #4

EXPERIMENT		
Purpose:	1.	To show that different substances conduct heat at different rates.
	2.	To distinguish between conductors and insulators.
Materials:		Bunsen burner, clock, strips of steel, copper, aluminum, glass tubing, blackboard chalk, wood splinter, beaker, water, slate (a rock).
Method:		Hold what you are testing about 6 cm from one end and hold that end into the flame of a Bunsen burner. Time yourself and see how long you can hold on to it.
Observations:		Conducts heat well. Doesn't conduct heat well/time.
Conclusions:		Give a definition for the word "conductor."

Friday
Mr. Henning begins class by talking to those who were on a trip the day before:

> "Now just for the people that were away the other day, remember, please do not walk off with the activity sheets. Do not write on them unless I ask you to put something on them. Please return them at the end of the class. If you need one because you are behind, you have a couple of options. You can come in and see me. You can borrow somebody else's. As a last resort I will let you take one out of my classroom. [Activity groups are arranged.]
>
> "Now, as I mentioned to the class the other day, this is a very very crowded classroom. Another slight problem that we have is that we don't have enough aprons and goggles to go around for everybody in the class. Because of that we're going to have to take turns lighting the Bunsen burners and doing the actual experiments. Now that doesn't mean you have to sit at your desk. You go

to your group area as long as you're not standing over the flame and as long as you're standing back a couple of feet. You'll still be able to see. I just don't want any accidents to occur. Any questions?

"Again, as I said, the people that were away yesterday, everybody in the class — hang on, David, put your pen down till I tell you to start. Elizabeth, pay attention. Put your pen down. Then I know you're paying attention.

"The way we're going to do these experiments, I'm going to do some of the work for you. I will put down the purpose, the materials, the method by which the experiment will be done. You will have to do the observations, obviously, the conclusion, and a diagram. So I will help you out; I will give you a sheet with those first pieces of information. You have to do the rest. That's why it's important that you work together as a group so everybody gets some feedback, the information. [The groups turn to the activity. After that Mr. Henning calls for clean-up.]

"You have three things to do. You have to write down your observations. Now obviously it may be only one person that's taken down the readings. That means that everybody in the group will have to copy them into their notebooks. Two, you have to think up a conclusion. What did you discover? I'm not going to give you a hint here. Three, you draw a diagram. A nice simple diagram showing a Bunsen burner with a flame, a little hand holding onto the object, and that is it. The diagram will be a half-page in size. It will be drawn in pencil. It can be pencil-crayon if you wish. Any questions? You've got work to do. Do it."

Later I asked Mr. Henning why most of the "experiments" require a diagram.

"Well, the main premise is that when they go back and look over the notes, they may be able to read through the material but for some of the kids, if they have a little picture that they can look at, they'll say, 'Ah!' When a kid reads over his notes, he's going to go 'bloop'; but if he can look at a picture, he'll remember the whole experiment. Even though he can't regurgitate it word for word, he'll have a good idea of what he did – hopefully, if his diagram's labelled and drawn with any accuracy. I think, again, that's a part of the scientific – the experimental – process; you know, that you can do a diagram after and actually see what you've done."

Monday

Mr. Henning begins by circulating around the classroom and briefly looking at the write-up on Friday's activity with conductors:

Henning: Now looking around I see a few slight problems. Number one, some of you people still don't know how to write out a note. You use pen, you don't use pencil. I see a lot of messy attempts. Those people who have used a fairly blunt pencil will be redoing it, I'm sure. Next, the diagram that you were supposed to do is absent in some cases. Some of you have done it and you have not labelled it. [Looks at a student's diagram.] That's good, Ray. So remember you need a labelled diagram.

Scott: How do you label it? Like this?

Henning: Shhh! You have a question, Scott?

Scott: Yeah.

Henning: Put up your hand, please. [Scott puts his hand up.] Yes?

Scott: Do you say what it is or what?

Henning: Well, if you have a diagram and it's not labelled, it's not a complete diagram, meaning, you should label that you have a Bunsen burner there and label whatever object you're representing that by — if it's an aluminum strip or whatever the case may be. O.K.? So as you can see, there are a few problems, but I realize this is your first attempt at an experiment. If you learn it correctly the first time, we'll have no problems with the future experiments that we do.

Let's take a look at the observations. I realize that because you all worked in different groups the observations that you found concerning the amount of time it took for the various materials to get hot would differ from group to group. But we should notice something about these observations and the observations will be literally summed up in the conclusion. So let's look at the conclusion and we'll see if we can see the relationship between the conclusion and the observation. The conclusion. Who would like to read out the conclusion? Peter, can you give me your conclusion please, or one of them?

Peter: Metal conducts heat the best.

Henning: O.K., and looking at your observation, how did you determine that?

Peter: Well, the aluminum and the copper and the steel conducts heat very fast, but the chalk and the glass tubing and the wood and the rock didn't.

Henning: How many people would agree with the conclusion Peter arrived at? Good. Does anyone have any other conclusions that you could mention? Matt?

Matt: Different people have different sensitivities to heat.

Henning: O.K., interesting. Could you give me an example of how you arrived at that conclusion? [Matt's response is inaudible.] Interesting. Does that relate to the purpose of the experiment though?

Matt: No.

Henning: No, it doesn't. But that's O.K., it's an interesting sideline. It doesn't exactly relate back to the purpose, but as Matt said, obviously some people may be more sensitive than others and perhaps they could feel the heat more quickly. [A short interchange occurs with another student concerning the conductivity of chalk.]

Henning: So what would we call that type of material that does not conduct heat very well? Frank?

Frank: Unconducted.

Henning: Unconducted. Well I think there's another word in here. Isn't there a word in your "purpose" that will maybe give you a better word instead of an unconductor? Lynn?

Lynn: An insulator.

Henning: An insulator. Right. Some materials act as insulators because they do not conduct heat very well at all. [A short interchange occurs concerning why one student had a low time-reading for chalk. Then Mr. Henning slides the blackboard sideways to expose two written statements.] O.K., on the front board I wrote down a typical type of conclusion you can have. Now this isn't what everybody has to have, word for word. This is just the ideas that you should have been able to pick up. For example, Conclusion #1: "Metals are better conductors than nonmetals." In other words, the aluminum, copper, and the steel, and the iron all conducted heat relatively well, whereas the materials such as glass, rock, and chalk, for example, are very poor conductors of heat. And then I put down in #2 – I left two blanks: "[blank] conducted heat the fastest while [blank] was the worst conductor." In other words, what you can do is just fill in the blanks. For example, aluminum may have been the best conductor we found, and chalk or rock may have been the worst conductor you found in your group so that way you've got two conclusions and you related them back to the purpose. You should also mention the word "insulator." You could use that as another word to relate to your conclusion. And also, as you see, a very quick simple diagram labelled "Bunsen burner." That's all that's necessary with this diagram for this first experiment. It doesn't have to be terribly elaborate. [After several brief interchanges, Mr. Henning hands out an activity sheet on water convection. The procedure is to heat water containing crystals of potassium permanganate in order to "see" the convection currents. The purpose is "To find out how water gets hot, even though it is a poor conductor."] O.K., just take a look at the purpose of this next experiment. I gave you a couple of seconds of time and the experiment's pretty well all set up at the stations. Purpose. Steve, could you read out the purpose, please?

Steve: "To find out how water gets hot even though it's a poor conductor."

Henning: O.K., so in the first experiment we're dealing with solids. This experiment we're going to see how a liquid such as water is heated. Some of you already have an idea. [Mr. Henning continues the instructions with Activity #5.] Does anyone have any questions? I'll tell you what, I'll give you five minutes right now to start copying that down. In five minutes put the aprons and the goggles on and we'll start.

Student: Do we keep these?

Henning: No you don't keep those. Again you do not keep these handouts, please. You copy them. [New group leaders are chosen and the class works on the activity until the end of the period.]

Tuesday

Mr. Henning moves among the students, looking at their activity sheets from Monday. Students are mumbling.

"Now, from what I've seen so far, I shouldn't hear a sound out of any of you. In fact, I haven't seen one person so far that has it all done. It's not a very good way to impress me. [Moves to the next student and comments on the diagram.] What is that? I can hardly see it. Get another pen and do it all over. [Moves to the next student.] Why is it in pencil? Do it all over again with pen. [He moves from student to student commenting on their work, then summarizes.]

"Well, looking at the experiment you did yesterday, it's not finished. Pens and pencils down now, everybody listen. Brock, be quiet please. Now I can't really figure out why there are so many people in this class that couldn't complete the work I asked you to last day. It wasn't terribly strenuous. That's why I figured you could all handle it on your own. A number of people could. Obviously that shows that they could accept some responsibility. Put your pen down, Linda, and listen to me.

"Now, the things you had to do: you had to put in an observation, you had to put in a conclusion, and you had to draw a diagram. Some of you did the observation, some of you did a diagram, and some of you did conclusions, but very few of you did all three. The experiment's not complete until you've finished it completely. [Later, Mr. Henning said that he occasionally "put on a show" in order to get students to work.]

"Now, what observations did some of you notice?" [The class turns to a discussion of Monday's activity, followed by another activity on air convection.]

With these excerpts I have tried to convey, in summary form, my impression that Mr. Henning's emphasis on routine and responsibility tends to be played out at two levels. One level concerns general issues of classroom control or socialization (e.g., "Everyone put their pens down"), while another level concerns routines more specifically related to the work in science (e.g., experiments require a diagram). Obviously, the two levels are not mutually exclusive (e.g., diagrams must be done in pencil, notes in pen).

The substance of the students' work and class discussion is generally circumscribed by the activity sheets. On the whole, students' questions tend to be procedural but, on the few occasions when students asked questions of substance, Mr. Henning was willing to let discussion move in the direction indicated, even though he may not have had a ready answer (e.g., "Sir, what makes a flame hot?"). Mr. Henning comments:

> "I guess it [questions from students] happens occasionally. I can think of a few other times that they'd ask me a question, and maybe one way of answering it would be 'O.K., what do other people think?' or, 'What do you think?,' or give them part of an answer and then send them to the library to check it out some more or something."

Insofar as class work and discussion tend to be confined to the activity sheets, "learning the basics" is emphasized. Mr. Henning's goal of relating science to everyday life, while not normally provided for in the activity sheets, generally is brought out in class discussion either by examples provided by Mr. Henning (e.g., relating air convection to heating systems) or by questions he poses to students.

Mr. Henning enjoys teaching, and this fact was borne out repeatedly in observations and in discussions with him. Most professions have their frustrations, however, and, as any teacher knows, teaching is no exception. When asked about frustrating aspects of his work, Mr. Henning's initial response was, "The thing that bothers me most is their [grade 7] lack of manners and respect, generally speaking." As the days went by and we talked more, it became apparent that a considerable portion of that frustration was due to the behaviour of the general-level students. Mr. Henning feels that much of the difficulty is a matter of innate intelligence ("They're [the general-level students] going to produce children that, generally speaking, are going to be at a disadvantage, and I believe that they're not going to have as much to start with.") as well as environmental factors, such as a broken home. I asked Mr. Henning to describe the major difference between advanced and general-level students. "Maturity, effort, responsibility, brain power, manners. No comparison. It's just like night and day. It's unbelievable."

During the one day that I spent observing all of Mr. Henning's classes, his frustration with classes containing a high proportion of general-level students was evident and understandable. From my point of view, there was a much higher proportion of "drill-sergeant" controlling behaviour by Mr. Henning with the general-level students, usually as a result of things students said or did. Over the course of a month, I developed two interpretations of the source of the disturbance felt by Mr. Henning. The general-level students (especially the small handful that can seriously influence the tone of an entire class) are, comparatively speaking, unpredictable, both academically and behaviourally. And the general-level student makes the teacher be something (e.g., a drill-sergeant) that he or she basically does not want to be. When we were discussing one particular "problem" student, Mr. Henning commented that the student would frequently laugh when someone made a mistake:

> "He just doesn't control himself, in that respect. That's what bugs me. That's the main reason — I shouldn't say I dislike them — I like them least of my other classes. That's the thing there, it's the discipline: keep quiet, sit down, no, yes, don't do that, don't do this."

But there are joys in teaching, too, and one of the more conspicuous joys for Mr. Henning is just being around young people, as shown by his involvement in extracurricular student activities:

> "O.K., as you know, Bill, Ron and I do the Friday night club [dances]. That's only one Friday a month. . . . Sports take up a couple of nights a week; the swim club on Tuesday mornings; the staff-student hockey on Wednesday and Friday morning. . . . Actually, we just started [the swim club]. . . . The girls had a swim club, and they had about 50 girls and the guys said, 'Oh, we'd like to have one of those, let's have one,' so Bill and I decided to give them a swim club and we had our first meeting last Tuesday."

Grade 8

Mr. Sills' class has just seen a filmstrip on ways to conserve energy in food preparation and is discussing a series of questions on the filmstrip.

Sills: How could we prepare foods in order to conserve energy?
Student: We could eat raw foods.
Sills: All right, another one?
Student: Cook with a wok.
Sills: O.K. Do you know a country that they've talked about recently that has been eating dogs? Yes?
Student: The Philippines.
Sills: The Philippines. Well, there's a new cook book out in the Philippines. It's called *How to Wok Your Dog.* [pause]
Students: Ohhh!! Ohhh!! [much moaning and laughing]
Sills: I know, that joke was in bad taste. [The discussion continues.]

Later, during an interview, we discussed this episode:

Kilbourn: Bad puns are part of your style.

Sills: A terrible part. It's just a little bit of humour to brighten things up.

Kilbourn: But you consciously do that, I take it.

Sills: Oh yeah. I mean, I think teaching is predominantly the acting. You have to have a little bit of levity just to make the kids feel comfortable and know that you are human and you may tell a rotten joke now and again. It's all part of the game, eh?

Ron Sills has taught elementary school for 10 years. This is his first year teaching in a junior high school and his first year teaching full-time science. He has six grade 8 classes and three grade 7 classes. His BA degree is in psychology, and he is currently working on an Honours degree. He has moved into the junior high system because he felt he was "getting in a rut." Mr. Sills remarked on three major differences between elementary and junior high:

> "There aren't too many differences between grade 6s and 7s as far as the students are concerned. However, I notice a vast difference in the 8s as far as maturity level goes; the girls especially — not the physical aspects, but definitely attitudinally — are sort of feeling their oats, and they don't really like to get down to serious work.
>
> "It's a whole new ball of wax to me, giving marks, and I'm already beginning to see injustices in the system. I was talking to Steve Henning about the marks and how I feel that marks aren't necessarily an indication of the student's performance at the junior high school level.
>
> "You only see the students for 40 minutes during a day and you only see them three or four times a week and you don't really get to know the students as well as you do in an elementary school, which is too bad. There are some students in grades 7 and 8 that I barely get a chance to talk to, simply because I have a subject to cover and I have to do it in a 40-minute time slot. . . ."

Because he is new to the situation, Mr. Sills is feeling his way and is gradually developing ideas about what he will do differently in the future. For example, his grade 8 classes started the year with a unit on classifying living things, are now doing a unit on energy and will next do a unit on reproduction. It had been suggested to Mr. Sills that he simply follow the sequence adopted by the previous teacher:

> "This is my first year doing this, so if I had to do it over again I would arrange it so that it would be in a totally different sequence. I don't exactly know how I would arrange it because I haven't really given it a great deal of thought yet, but I definitely would, in my planning, arrange it so that I would have continuity."

During our first interview Mr. Sills commented on his goals as a teacher:

> "My main emphasis in teaching is to make the kids feel comfortable in what they're doing. That's always been my basic philosophy.

I'm not a strict disciplinarian, and I definitely feel that one of the things that has been my ultimate goal for the past 11 years is to just make kids feel more comfortable in education in general, and to not make them feel threatened. I would like to see students come out with a basic liking for the subject — broadening of the horizons. A lot of kids are turned off by science simply because they are overwhelmed by the material."

From a questionnaire listing 14 goals for science teaching, Mr. Sills selected "developing social skills," "developing attitudes appropriate to scientific endeavour" and "understanding the role and significance of science in modern society" as very important overall goals in science teaching. More specifically, with regard to the "Wise Use of Energy" unit, he made this comment:

"What I have been talking about basically is nonrenewable/renewable energy sources and how to use these sources. The students have come in with a set of ideas, hopefully about energy and where energy comes from, and what I have done is I've sort of broadened that scope, so to speak. I've taken that knowledge and I've expanded on it or I've added to that, hoping that the student will have a better working knowledge of the terms. Hopefully, I could get these kids to go home and say, 'Gee, we're being wasters, and this is happening all around us.'"

Because there is no ministry-developed unit for the "Wise Use of Energy," Mr. Sills has developed one on his own. The following sequence of topics is the basis for the 16-lesson unit: potential energy, energy conversion, renewable and nonrenewable energy sources, advantages and disadvantages of different energy sources, energy in the home, solar energy and the water cycle, energy conservation, energy and food preparation. The lessons are structured around films and filmstrips (seven are shown) and activity sheets (generally, one per lesson). Normally, the activity sheets are a series of questions on the filmstrips or, sometimes, on the text or other material. Although the department head encouraged the idea of activity sheets, Mr. Sills develops them:

"Being a new teacher, of course, I have got to make use of the prep-periods, and I find that they go really quickly. Usually Friday night I stay home and work [on the activity sheets]. It's almost like a prefabrication. But it's true. Work on it Friday night, and then Sunday night from about 7:00 till almost 11:00 I'm working on course material. And then during the prep-periods, of course, I'm previewing films."

A typical pattern of activity for a 40-minute lesson is for the class to see a filmstrip, copy and answer activity sheet questions and then discuss the questions as a whole class. For this particular unit, the students usually work individually or, occasionally, in groups of four or five, doing the same task at the same time:

> "When I was doing 'Classification of Living Things,' I had a whole different system, as a matter of fact. I had four groups, and I had four activity sheets which were rotated every day. At this table I had a whole series of glass jars with specimens in them, and the kids had to classify the specimens. At the next one I had the micro-slide viewers and they had to look at the micro-slides and write a few things on the activities there. And on the next table was a text-book activity. The last table had slides and a tape. And I also had a library activity — I had a word search."

The class I observed for most of the unit was designated "advanced" and was very large — 37 students. Although the classroom was pleasant and well equipped, it was quite small, and Mr. Sills agrees that the overcrowding constrains both what he can do and what he is willing to try to do.

In the following account, I extract and comment on relevant excerpts from the sequential lessons. No one excerpt could be considered typical, but taken together they form a relatively adequate image of the structure and substance of Mr. Sills' teaching during the period of observation.

Friday

This is the fifth lesson in the unit. The students read six pages from the text (of which there is only one class set) and work on the activity sheet that sets them the following task:

> "Describe each of the following energy sources: geothermal, solar, nuclear, hydrogen, wind and tidal. What are the advantages of each? The disadvantages?"

The information needed to do this task is contained in the text. Throughout the observations, the questions on the activity sheets and in class discussions generally are "recall" questions (although there are exceptions). The students' written work is collected about every eight days, marked, and returned.

> "I mark them holistically, according to neatness, accuracy and completeness, and I don't worry about spelling mistakes or anything like that."

On the whole, for this unit, the texts are seldom used, largely because they contain relatively little information on the topic. I asked Mr. Sills how he normally uses the texts:

> "Very sporadically. If I use a textbook at all it's for some questions that I couldn't dream up myself related to the unit, or I would take diagrams and specific charts out. In the unit on asexual and sexual reproduction, for example, there are going to be oodles of diagrams and charts that I want the kids to have in their notes."

After the class has worked on the activity sheet, Mr. Sills holds a class discussion. Here is an excerpt from a total class discussion of about 15 minutes:

Sills: All right, great. It doesn't take a lot of uranium to create this power. That's right. Another advantage? O.K., go ahead if you have an idea. Just shout it out.

Student: Is uranium renewable?

Sills: That's a good question. I'll throw it out. Do you think uranium is a renewable resource? [mixture of students saying "yes" or "no"]

Student: No, I don't think it's renewable.

Sills: No, it's not. O.K., that's one disadvantage, that's right. However, because we've got a lot of it, the uranium is going to last us.

Student: Doesn't it cost a lot to get it?

Sills: Getting the uranium doesn't, but building the power plants is a very expensive problem. However, it's not as expensive as building great dams, or gathering the potential energy of waterfalls. The next one. Oh, the disadvantages, of course. Yes?

Student: Kill people.

Sills: All right, how?

Student: The radiation, unless it's properly controlled.

Sills: All right, great. Another disadvantage? Yes?

Student: People don't like it.

Sills: All right, why?

Students: Because it's dangerous. Because of radiation. Nuclear wastes are — I mean some of them aren't properly, you know, contained or whatever.

Sills: All right. Great.

Student: It's hard to dispose of the nuclear waste.

Sills: That's the main problem right there. That's a great disadvantage. I'm glad you people are thinking. That's super. All right, let's take a look at hydrogen. First of all what is it?

Student: [inaudible]

Sills: I don't want the same people answering all the time. That's great that you are doing that [turns towards some silent students] but I'm looking for a description of hydrogen? Yes, Trudy?

Tuesday

Mr. Sills begins the class with these remarks:

"Today we are going to have a look at still another filmstrip. I realize that you are getting a little bit tired of them, as I was too. However, the next day that you come in you will not be looking at a filmstrip; you will be doing another exercise related again to the textbook. Today we are going to be looking at energy use at home.

And in particular it's sort of in part related to an activity that we are going to be doing several days from now, where I am going to be asking you to look at the energy use at home and you'll be keeping a chart of some of these things that you use at home that demand the use of electricity... [continues to talk about conserving energy]. There are several things that we can do in the home to save energy, of course. And several of them are listed in the filmstrip.

"Now, the question that I jotted down — a lot of people think I get these questions with the filmstrip. I do not. I sit and listen to the filmstrip and as the filmstrip is going on, I jot down the questions that come to my mind — simply for the fact that it's easier for me to recall the filmstrip than it is, in the long run, for you to recall it. Anyway, let's have a look at it. I'd like to read these to you because the filmstrip tape goes very, very quickly."

At this point Mr. Sills reads the 19 questions from the activity sheet. The first seven are as follows:

1. Where does 20 per cent of all Canada's energy go?
2. What does this figure not include?
3. What happens to a poorly insulated home?
4. What per cent of the budget is used in heating a home during the winter?
5. What steps can be taken to ensure that homes will be comfortable year round?
6. What will good insulation do?
7. What savings in oil will result?

After this introduction, students watch the filmstrip, write the answers to the questions and then discuss them. On this occasion they are allowed to keep the mimeographed activity sheet, though normally they spend time copying from a class set into their notebooks. Two aspects of Mr. Sills' preliminary remarks are characteristic: he publicly reflects on what he is doing as a teacher, and he relates what the students are presently doing to what they will be doing.

Thursday

Student: Where do we find the answer to number two?

Sills: From the "old noggin." The reason I asked these questions was to get you to think.

The tasks on this activity sheet are more demanding than those on the previous Tuesday. For example, students copy (from the text) a diagram of the water cycle and a chart showing what happens to the sun's energy (35 per cent reflected, 43 per cent absorbed, etc.) and are asked to answer the following question: "One of the sources of energy depends on the water cycle, which is powered by solar energy. State what limits this source." The class spends the entire period working on this and another question. During this time I followed Mr. Sills as he worked with individuals. Here he is talking to a group of four students:

> "I'm not talking about the water cycle. The water cycle is fairly easy to understand. If you think about the sun — it's giving out 100 per cent of the energy that the earth takes in — it will become a little bit clearer. Don't worry about the fact that the total radiation is [so much] per year. What is more important is that the earth takes in 100 per cent of the energy from the sun. It gives 100 per cent of its energy, but right away what happens is that 35 per cent is directly reflected back into space from the clouds. We never see that 35 per cent. All right? It says that approximately 43 per cent is absorbed as heat energy and power in the water cycle. Well, this is the reason I had you draw the water cycle so you could see that, of course, we have to have the sun's energy for any type of evaporation to take place. Look at the diagram of the water cycle you are about to draw."

Monday

There was no class the previous Friday because of parent/teacher interviews. Mr. Sills makes this comment to the class about the interviews:

> "First of all, I'd like to say that I've met a couple of parents on the first day for parent/teacher interviews. It was nice to see a couple of parents. It's usually the parents of relatively bright children that end up coming to these interviews, which is too bad. There are exceptions."

After ten minutes, two-thirds of the class leave for tubercular skin tests. The class is given a one-page article entitled "Why Conserve Energy" accompanied by a diagram (from a book on home insulation). The article is read aloud, one paragraph per student. The remainder of the period is spent writing the answers to activity-sheet questions on the article.

Tuesday

Class begins with a brief discussion of sources of renewable and non-renewable energy. Mr. Sills then shows an interesting National Geographic film on alternative sources of energy. Later I comment that most of the films and filmstrips appear to be from the United States:

> "I was going to say that I don't actively look for Canadian or non-Canadian materials. I think that I'm more interested in materials that I find available."

The class discusses the film for about five minutes.

> "What I would like you to do in the remaining five minutes is to take a look at some of the alternative sources of energy, and I would

like you to write a few lines — just a few lines — on the alternative source of energy that interested you the most and why it did. [Bell rings.] What I would like to do before you go is — I would like to have you do that for a [homework assignment]. I haven't given any homework up to this point, and I would like to have it completed as a homework assignment, as activity number 10, and I would like to hear some of your answers in the next class and that will be the first thing that I will take up with you."

Wednesday

The class did not meet on this particular Wednesday, but I was with Mr. Sills for the entire day — three grade 8 classes and three grade 7 classes (none of these classes was taped). This is an appropriate point to make two rather general interpretive comments that were more firmly established for me as a result of the day's observations.

The first observation is that, if possible, Mr. Sills tries to keep his classes on the same topic at the same time, or at least within one or two days of each other. This approach is largely a response to the logistical complexities of trying to coordinate equipment and supplies for several sections of the same grade — a task that becomes more difficult the further the sections get "out of step." And, as Mr. Sills pointed out, he wanted his classes kept together so that he could test before Christmas, grade over the break, and start fresh with a new unit in January. One of the consequences of trying to keep classes together (exacerbated by assemblies, special programs, TB tests, etc.) is that sometimes some classes are rushing to catch up, while others are stalling.

The second comment concerns a variety of factors related to general-level students, discipline and teacher frustration. Mr. Sills has two grade 8 classes that are considered "low" and a third class that, though average, is seen as a definite control problem by the whole staff. The term "low" is often (but not always) used by Mr. Sills and other teachers at McBride chiefly in reference to students that are thought to have low academic ability, little motivation, and a tendency towards inappropriate behaviour. Throughout the period of observation with Mr. Sills, he referred to his "lows" in a way that indicated they were a source of frustration and, at times, considerable anxiety. "I'm exhausted after having class" and "I'm not looking forward to next period because. . . " were typical statements. Apparently, some of this is related to Mr. Sills' relaxed approach in class and his inexperience with grade 8 adolescents. Steve Henning and Bill Larson have encouraged him to "get tough."

Mr. Sills and I talked about the "lows" on several occasions. He feels that some of the difficulty is that "low" students tend to be concentrated in a few classes. Some of the stress lies in their unpredictable nature:

"I can't predict. [Class B] is unpredictable. Now today they threw me for a loop, they really did. They were really excellent but it was something that the [National Geographic] film had done and certainly not what I had done. . . .

"If I gave [Class C] a task I don't think that they have the attention span that would enable them to finish, or they might start it and may last for about 10 or 15 minutes. Then they would say that this is too hard – one of their favourite expressions is 'This is for a browner class,' a brain class. The kids have a notion of where they stand as far as the relationship with the rest of the grade 8s. They know that they are the bottom, which is unfortunate.

[Earlier in the same interview:] "There are single parents, you know? More so than ever. The kids come into class and they have all these psychological hang-ups because of a one-parent type of thing, and you're dealing with that. And the stress is all around you, and you just sort of have to bear under the pressure I guess.

"You're seeing [the advanced class] and there are very few kids in here with any major hang-ups; in a lot of the classes that I deal with there are. I have one boy. . . [who] doesn't have a father, and he sits there and he dawdles away his time. He's had seven failures this term, and his mother came in for the interview. I was talking to her on Friday and she was crying. What can you do? What can you do as a teacher? You make specific recommendations. I recommended that he have the benefit of psychological services just to see where he's at academically and to see what his interests are, but I don't think the mother goes for it. But as a teacher you can only do so many things."

Thursday

Mr. Sills begins class with a harangue (the transcript of which fills one page of single-spaced type) concerning an incident from a different class that morning. This passage is illustrative:

> "I know for a fact that most of you people in the class are bright enough and intelligent enough that you would do your homework at night and not in somebody else's class. That is something that is a definite 'No.' I'd rather have you say that you hadn't done the assignment, rather than do it in somebody else's class."

Later, I asked him if similar incidents had occurred in the class I was observing and to which he was speaking.

> "Oh, no. Well, there were some things that went on, but also it was my devious way of getting them to do their homework assignment, like as if to say, 'You guys wouldn't pull this stunt on me, would you, in not doing your homework?'"

During the harangue, however, I recorded my impression that some of the fervour could be attributed to emotional "carry-over" from the event which occurred in Mr. Sills' most obstreperous class. When he finished, Mr. Sills turned to a discussion of the homework assignment from Tuesday (as promised) and the class ended with a film from the National Film Board.

Tuesday

I could not attend the class on Monday. Mr. Sills had asked the students to write the answers to several questions, and he began this class by referring to them:

Sills: Some of you have done the answers to those questions. Maybe we could have a look at the first one and see exactly what your impressions were. What would happen if we were to eliminate all of the electrical gadgets in the world? What do you think would happen? Yes? [A number of students raise their hands and begin to talk at once.]

Sills: Ah, I beg your pardon. Let's put your hands down for a minute. First and foremost, a couple of things that you should be aware of is that you are forgetting that people are speaking. There are people with their hands up that wait. The second thing that you should be aware of is that while that is happening, other people are talking to their neighbours. That is unforgivable. O.K., Ali?

Ali: I think that electricity is one of the cheaper sources of energy and if you did that I think it would help a lot but I don't think it would solve all of the energy problems.

Sills: O.K., you made a statement there. You said that electricity is the cheapest form of energy.

Ali: No, I said one of the cheaper.

Sills: Um, I would like to sort of argue that point simply because electricity comes from sources of energy that are not cheap. O.K.? At the present time anyway.

Student: I think some of the gadgets you should cut, like electric toothbrushes and shoe shiners and orange juicers and things, but I think that some of them — dishwashers even you could cut out. But I think some of the things like dryers and that, people need it in today's society, and I know that there are a lot of people who really use it.

Sills: O.K., so you say there are a lot of things that we could eliminate and others that we could keep. [The lesson continues.]

Sills: Great. That's a good statement to make. Yes? [A student's inaudible comment is laughed at by several other students.]
One of the things that you should be aware of as well, and this is a typical reaction to someone who makes a statement. What I would like you to be aware of is that this is an open forum, and it's an open forum that shouldn't be criticized.

You shouldn't criticize anyone who has a statement to make. O.K.? No matter if the statement is sort of off base. At least it is a statement that this person genuinely feels is a viable type of statement and it shouldn't be criticized. Anybody can say anything directly related to the question and shouldn't be criticized. Maybe we've made that a rule then. If you make a statement, then it's a statement that you feel is right. Fair enough?

Student: If we took out electrical gadgets and things, I mean come on, we'd be back like the pioneers. We'd figure out other ways to do it, but I don't think people are ready to give it up right now.

Student: If we did – say if we did – and then all of a sudden we didn't like it and we wanted to change. . . [inaudible].

Student: I think we should find more ways to conserve our energy because if we find ways to conserve the energy then we'll have enough energy and we won't need log cabins.

Sills: Great. [Lesson continues with considerable student participation.]

Later, during an interview, I asked about this episode:

Kilbourn: There was the other day in which the class made some good comments, but some kids would laugh, [and you said] "Hey, wait, that doesn't go here." Do you very often make "process" comments like that?

Sills: Quite often. Quite often. Especially when I think the behaviour is going to be detrimental to the class. If I think that the behaviour is going to carry on, I will make a "process" comment because I – well, simply because I don't want it carried on in the class. If I did that – it also gives the person who made the comment a feeling of importance as well. But often kids are put down, you know. I sort of unintentionally put Barb down over here. I didn't really mean it.

These affective issues spread beyond the classroom interaction, of course, and it is apparent that Ron Sills likes the students and spends considerable time with them outside the classroom. He is in charge of the computer games and the pop concession at dances, he helps with the school musical, he is starting a computer club and he is trying to decide whether or not to help some students with a rocketry club. I suggested that the whole science department seems to have a high social profile. His reply:

> "Well, don't forget that basically you're a teacher first and a science teacher second, and as it turns out, all three of us – Bill, Steve and I – are all sort of socially oriented, which is terrific. We have a great deal of interest in the social activities that go along with school."

Grade 9

The bell rings. Corridors come alive with students going to class. Bill Larson stands outside his door while class "A" begins to fill the room. As students enter they automatically pick up an activity sheet from the corner of Mr. Larson's lab table, go directly to their seats, start reading the instructions and begin copying the activity sheet into their notebooks. Mr. Larson enters and goes over the instructions. Usually the instructions concern procedural matters. The class then begins to work on its own in eight groups of four students each. On a typical day they will move to the lab counters (running the length of the double room) where Mr. Larson will have placed all the necessary equipment to do the exercise. While the class is working, Mr. Larson circulates among the groups, dealing with questions and problems individually. He also does routine "accounting" — checking with individual students about work they must turn in, or crediting them with work they have done. A few students move about tending plants, several small animals and a weather station. When the lab is finished, students move back to their desks and begin working on diagrams and answering questions. Sometimes, but not usually, there will be a brief class discussion of the work. Near the end of the class Mr. Larson calls for clean-up. Each group readies its lab area for the next class while one student collects the original activity sheets, counts them and puts them on the corner of the lab table for the next class. Students sit in their seats and check the floor for garbage. The bell rings. As with Mr. Larson's other classes, this class is run efficiently and students are well-trained.

Bill Larson is head of science at McBride. Every day he teaches one class of grade 8 mathematics and five classes of grade 9 general science. He has been teaching for 12 years; some of that time has been spent at the secondary level, but he prefers junior high because he feels that, on the whole, the students are less set in their ways and, consequently, the atmosphere is more exciting. He took mathemathics and science in his BA degree program, and he is currently enrolled in an MEd program specializing in environmental education.

Goals

As department head, Mr. Larson has had considerable influence on the science program at McBride, especially as Ron Sills and Steve Henning are new to the situation. For example, he has promoted the use of activity sheets as a structural format in all three grades. The use of activity sheets embodies Mr. Larson's belief that one of the most important aspects of teaching is to get the students involved and feeling good about what they are doing. I asked him what he thought it was important to communicate to students, and why he teaches the way he does.

> "I guess it's just to get the kids involved with the subject. I believe that they learn by doing and being involved. I can think of the

things that I have enjoyed the most and they're the things I feel a part of, the things I feel good about doing and things that I'm successful with."

Along with involvement and success, Mr. Larson puts a high priority on students learning to be accountable and developing a sense of responsibility. On one occasion he talked about his implicit messages to students concerning responsibility:

Larson: I didn't even tell them. I may have, just off the cuff, said yesterday, "Oh yeah, by the way, tomorrow your notes are due," but I didn't make a big production of it. They know when the stuff is due for the rest of the year, within a couple of days. I mean they can figure it out, and they know when their tests are. Like, I'm not going to change the format for the rest of the year as far as the activity sheets are concerned.

Kilbourn: Part of this, I take it, is a thing that you work on continually, which is accountability and responsibility. You're fairly persistent about that from what I've seen.

Larson: I guess it goes down in my whole philosophy about teaching kids. Like, I want to make them responsible for their own actions. I think our society as a whole would function a lot better if all of us were responsible for our own actions. I feel that there are too many cop-outs and I don't think I'm doing a kid a favour if I let him get away at least without thinking about it. I'm really a soft touch. I come on like Jack the Bear but I'm really a soft touch. [In a later interview:] I've always been big on social skills, especially things like cooperation, sense of responsibility. I'm a teacher, and science just happens to be the vehicle.

I observed Mr. Larson teach a unit called "The Functioning Animal," which followed the year's first unit, on green plants. He provided the following background information:

"I want them to understand some of the basic facts and concepts. I want them to understand digestion. I want them to understand respiration. We just touch on circulation. But it goes back to my game plan for the whole year. Like, it makes the other units make more sense if they do the [basics] at the beginning of the year. . . . It's kind of a first-term introduction – have a good experience, get involved, get into it, and the bottom line is I want them to come out of both these first units in the first term with some pretty good understanding of what green plants and animals are all about, and then we can go on.

[In a later interview:] "I have tried to order units in such a way that we build to a climax at the end of the year, which is that unit where we take them outside and do the environmental testing with the kids and things like that. . . . If you look at the course over the

> period of the year, it really looks like an ecology course, and that's the theme for the entire year."

Activity Sheets, Pace and Control

Activity sheets are the primary means for achieving goals specific to science and the particular unit. Mr. Larson is well organized; his files contain an activity sheet for nearly every day of the school year. Each activity is designed to be done in a 40-minute period. About 80 per cent of the activity sheets involve some kind of lab exercise, while the rest concern other resources (such as filmstrips) or printed material (such as the text). The sheets are normally copied by the students. (Mr. Larson expressed his concern that students spend so much time copying the activity sheets, and he has persistently encouraged them to get on with the tasks themselves. He pointed out that he would prefer to give each student a copy to keep, but the budget will not stand the expense.)

An observer cannot help but notice the rapid pace of most of the lessons, a pace that is dictated by both the amount the student must do and, more generally, the amount of material Mr. Larson must cover over the year as outlined by the Ministry of Education's guidelines. His comment:

> "I don't know what it's going to be like for next year, but for the two or three years that I've been here the increase in the amount of work that they've done between grade 8 and grade 9 is quite dramatic for them. I think it's just because either they're just too young to have the organizational skills or nobody's paid attention to teaching them those skills. . . . Maybe the odd activity sheet could be done perfectly in 40 minutes, but for the advanced kids there's always more. So that's kind of a philosophy where you don't really finish in here, you just run out of time."

The press for time can help account for several noticeable features of class "A." First, there is normally no "whole-class" discussion of the results or substance of the activities, nor is there generally time for talk about future lessons. Second, at least from what I noticed, students tend to ask procedural questions (i.e., questions that would help them finish the work) rather than broader questions about the material. (Non-procedural questions seem to be asked outside the classroom; class "A" students frequently and voluntarily come to Mr. Larson's room after school.) Third, although Mr. Larson never formally assigns homework, advanced students tend to do their class work in "rough draft" (especially drawings) and then copy the work to perfection at home. Finally, class "A" students are always "on-task."

> "I don't have a lot of rules — like a lot of little rules. My one major rule is that when you're in here, you're working. My thing is that there's a time to play and there's a time to work. . . . You have to watch where you draw the line between 'fun-fun' and 'involve-

ment-fun.' I think kids can have a lot of fun while they're doing something constructive. . . . So I try to make sure that all the resources are available, and then I just let them go ahead and work with what's in front of them."

In fact, Mr. Larson is in total control of his classes. One aspect of this control concerns discipline, and here it is evident that he runs a tight ship:

"It's never been my style to be really heavy with them. . . . [But you should] let the kid know that you disapprove, that he's doing something wrong: 'Nothing against you personally, kid, it's just about the dumb thing that you're doing right at this moment. Clean up your act while you're in here, it's inappropriate behaviour; now let's get on with the job.' And I find that works for me."

Another aspect of control concerns management of the class; and here, with the basic structure of the activity sheets and the accounting procedures, it is plain that Mr. Larson explicitly and/or implicitly controls what his students do and, in keeping with his emphasis on responsibility, expects that what they are asked to do will be done.

Outside the Class

Bill Larson's extracurricular activities stem in part from his concern for developing social skills. The high regard students have for him is obvious and, at least in part, is a function of the amount of time he is willing to devote to them outside the classroom. He is involved in staff-student hockey and in field trips (one week of camping and one week with general-level students at a field centre), as well as supervising dances, the student audio-visual crew, the photography club and the student prefects:

Larson: I've just looked around the school and found places where I thought that there was a need and used the need as a vehicle to get kids involved. . . . There are things that I can do with kids on an extracurricular basis. Like, you can relax when there's only a small group of kids. You can have some fun. Like, you can talk to them as people instead of as students. There's a distance that you have to keep when you've got 33 kids in your room. You can't get too close to them because then they just walk all over you, so you've got to play the heavy too. But with these kids you can kind of back up and relax with them some. And, I think understanding these kids helps me understand other kids too.

Kilbourn: Are any of your general-level kids in any of these groups?

Larson: Not this year, but that's just worked that way. They were last year. I had three or four kids last year from the general level. The problem with general-level kids is these jobs demand time out of class, and you get so much of a hassle from other

> teachers that for me, it's just not worth it. Like I need a kid to take a picture at three o'clock and he's supposed to be in typing and I can't get him out of typing to take a picture, so the program suffers because of it.

Class "A" and Teaching

The group of 32 students I observed could be described as very likable, cohesive, and academically aggressive. A number of the prefects for the school come from class "A," and volunteers from this class tend the plants, animals and weather station in Mr. Larson's classroom. We talked about the difference between Mr. Larson's class "A" and his two other advanced classes. He made this comment:

> "The kids in class 'A' have been hand picked. They're the instrumental music class, you know. Traditionally class 'A' has been the band and has been collectively of higher intelligence than the other advanced classes. [With class 'A'] you can get them excited about [the work] and they can carry it through to completion. Half those kids in the other advanced classes start petering out, maybe 10 minutes before the end of the period."

I was present for nearly all of the unit on "The Functioning Animal." Table IV.1 shows the titles of the daily activity sheets, all developed by Mr. Larson. Unless indicated otherwise, all the sheets require written answers to questions, a lab exercise and a drawing.

I have selected several excerpts from the observations in order to provide a picture of the operation of the class. As previously noted, Mr. Larson has total control of his classes. As a result, he had relatively few disruptions; one of the reasons for this is his persistence in control, even with class "A." For example, Mr. Larson began Activity #3, "Respiratory System of a Grasshopper," with a considerable amount of talk about what students were supposed to do and see. This statement followed:

> "Now this is the first dissection that you've done and you will get as much or as little out of it as you're willing to put into it. Like I said, they're not easy. You have to dig. Two things about dissections — we're going to be doing two more. First of all, we must treat them with respect. I don't want to see anyone practising darts with the pins. All right? If you're asked to open it up and pin it down, that's different. I don't want to see anyone flicking parts around the room or showing any type of disrespect for the material. . . . All right, the second thing is, if there's anybody fooling around while they're doing the dissection — especially because this is the first one, I want to establish some rules — an outburst of laughter or a scream or anything like that, you'll sit in the penalty box for the rest of the period. All right? The penalty box is your seat. You just have to get out of the action for the day. All right? I want you to ap-

proach this the same that you did everything else that we've asked you to do this year. Any questions about that?"

Table IV.1 – Activity-Sheet Titles for "The Functioning Animal"

1. How Living Things Breathe	(prepared microslides)
2. Determining Percent of Oxygen in Air We Breathe	
3. Respiratory System of a Grasshopper	(dissection)
4. The Breathing Organs of Humans	(seat work — textbook)
5. Digestive System of an Earthworm	(dissection)
6. Digestive System of a Frog	(dissection)
7. Digestive System of a Perch	(dissection)
8. Testing for Reducing Sugars	
9. Testing for the Presence of Lipids (Fat)	
10. Testing for the Presence of Protein	
11. Detecting the Presence of Water in Food	
12. The Gastro Intestinal Tract: Food	(filmstrip; no drawing)
13. Gastro Intestinal Tract: Glands and Secretions	(filmstrip; no drawing)
14. Gastro Intestinal Tract: Digestion	(filmstrip; no drawing)
15. Food and Energy	(seatwork — textbook)
16. Blood Typing	
17. Circulation	(seatwork — textbook)
18. Composition of Blood	(seatwork — textbook)

The following day, the class did Activity #4, "Breathing Organs of Humans." This activity required that the students work at their desks, read three pages from the text, and answer questions (for example, "List and explain the function of the following organs of the breathing system: nose, pharynx, trachea, bronchi, lungs"). Mr. Larson uses the text primarily as a resource. Usually, during "seat work" students are referred to specific passages or diagrams in the text. Students told me that they seldom read the text on their own unless specifically told to by Mr. Larson or by the activity sheets. Although Mr. Larson tends not to engage the class as a whole, except for procedural matters, he does circulate about the room and deal with questions individually. Here is an instance:

Student: I'm trying to find the function of the trachea, or whatever it's called.

Larson: The trachea?

Student: Yeah.

Larson: Now, where is it, to start off with?

Student: Windpipe?

Larson: Windpipe, right.

Student: It's the same thing?

Larson: Yup, the same thing. . . . Remember, it's the windpipe and it goes from the back of the throat to where it breaks out into the two bronchial tubes. . . . Remember yesterday you were looking at tracheal tubes from the grasshopper?

Student: Oh, yeah.

Larson: They connected the sphericals to the inner sacs. It's just the piping. You get the air coming from the outside to the organ of breathing. . . .

At the beginning of this period, Mr. Larson commented to the class about the workload — an issue provoked by some discussions with parents at Parents' Night:

> "Your parents, you know, are asking 'Is that normal?' and my answer to everybody that asked me was, 'Yes.' Remember at the beginning of the year I explained to you that you would be doing a lot more work than you did last year. Because you're in an advanced program, we're gonna pile the work on you and leave a lot of it for you people to do on your own. Your organizational skills are getting better, you're figuring out for yourselves what you should be doing in class and what you can leave to do at home. . . . You're in secondary school now, grade 9, year 1, so, you know, things do change. The workload does get a little heavier, especially in advanced programs. So don't get discouraged, all right? I think that you people are doing a fine job, as far as your notebooks are concerned and your day-to-day work, and that's a general comment to everybody."

On the next day, the class did Activity #5, "Digestive System of an Earthworm." This activity sheet, which is typical of many of the activity sheets in this unit, is reproduced in Table IV.2. In a later interview, Mr. Larson explained that the "recall" nature of the questions on the activity sheets and the final test is typical only of the early units, in which he is attempting to build a foundation for work in the second term, work that engages students in more complex material (such as ecological relationships) and more complex thought processes. The remaining two dissections (frog and perch) also pertained only to the digestive system. The "L5 Only" refers to "Level 5" or "advanced" students; all students receive the same activity sheets but only advanced students do the L5 portion. As he circulates about the room, Mr. Larson frequently deflects questions back to the students and a good portion of his interaction with students could be described as stroking, or maintaining rapport.

Table IV.2 – A Typical Activity Sheet

Functioning Animal Activity #5
Digestive System of an Earthworm

1. Cut the worm from mouth to anus with a sharp pair of scissors.
2. Using pins open the worm through its entire length.
3. Using charts, models and your text locate the following parts of the digestive system: pharynx, oesophagus, crop, gizzard, intestine.
4. Do a drawing of the earthworm digestive system as it appears in the tray. Label the parts.

L5 Only:
1. Explain how the earthworm digests food. To do this, list each of the parts mentioned in step 3 above and explain the function of each part in the system.

Larson: [Moves to a group of students.] Say, doctor, nice piece of surgery here.
Jill: [laughs]
Brenda: Let's go, we've got to draw it now.
Larson: Locate and identify the parts first.

Although Mr. Larson occasionally refers to previous work ("Remember yesterday you were looking at tracheal tubes from the grasshopper?"), there tends to be little explicit transitional talk as students move from one biological system to another in the activities. As Mr. Larson pointed out in an interview, those transitions are largely implicit in the logical sequence of the activities:

> "The kid should be able to see when he sits down with [his notebook] in front of him and he flips through it that we did the thing on breathing systems, organs and breathing and stuff like that; and we did the thing on the digestive systems; here are the physical parts; and we had a look at them; and now we're going to start talking about the chemistry of digestion."

The fast pace and workload were eased considerably with the four food tests (activity sheets 8 to 11). Even though these are simple tests and take only a few minutes to do (most students were finished in 10 or 15 minutes and spent the remainder of the time talking quietly among themselves), Mr. Larson intentionally has them do only one test (one activity) per day in order to give them a breather. The heavy workload picks up again with the three filmstrips on the gastro-intestinal tract. These filmstrips and associated activities involve a considerable amount of technical terminology (for example, "Define each of the following: pepsin, hydrochloric acid, gastric pits, rugae, chyme and rennin."). In these activities, Mr. Larson does address the whole class by going over the activity sheets and answering students' questions:

Student: What's cellulose?

Larson: After our green plants unit you ask that question? Think of your typical all-Canadian plant cell. What substance is it made from?

Student: Oh, yeah.

On the day before the multiple-choice test (which has questions of the form, "The small tube extending from the pharynx to the stomach of the frog is called (a) mouth, (b) oesophagus, (c) trachea, (d) gullet"), Mr. Larson reviews the unit by going over each activity sheet. Here is a sample of the review:

"'Number Five: Digestive system of an earthworm.' You cut the little critter apart. You located the pharynx, oesophagus, crop, gizzard, intestines. And for the Level 5 you were asked to explain what each one of those did as far as digestion was concerned. O.K.? So you should have some idea what the pharynx is used for, and the oesophagus, right? And you find that when these words are used, from organism to organism, funny thing, usually we're talking about the same part and usually the part has the same function. So, if we're talking about the oesophagus of an earthworm and the oesophagus of a human being, probably there's a connection. Because it's the same word and spelled exactly the same way, and has the same or very similar meaning, when you're talking about the two things. So, if you said that in the earthworm it's the tube that connects the pharynx region with the crop, then probably there's something about the oesophagus that is similar in other organisms.

"And, lo and behold, when you talk about the human digestive system, you can see that there's an oesophagus and it's a tube that comes from the mouth area and goes down in the stomach area. Now, the earthworm didn't have a stomach, but, if you looked at the definitions of those things, you could probably find something that may act as a crude stomach.

"Don't forget the earthworm — he's not a very developed critter. He's not exactly what you would call one of your higher organisms on the ladder of life. Who sits at the top of that, by the way? You've heard. You're looking at us. We, and other animals like us, are the most complex. O.K. What's the simplest form of animal life? If you start at the top with us and forms like us and move down through the different levels, what would you find at the bottom? The one-celled animals, eh? But whether you have one cell, or whether you have millions of cells, you still need food. You still need to get rid of waste materials. You still need to somehow digest that food. First of all you have to ingest it, and whether you have a mouth, or whether you just blob around it to take it in, the idea is still the same.

"Number Six:. . . ."

Hard and Fast but Interesting

I conclude this account with excerpts from some of the students' responses to my question, "How is grade 9 science different from the science that you had in grade 8?" (Readers should remember that these students have had neither Steve Henning nor Ron Sills for science in grades 7 and 8.)

Student 1: It's so much harder and there's more work. You get something new so you never know what you're going to do next. [In grade 8] you knew what you were going to do every day unless he started something else. And like the questions were easier and the workload wasn't as heavy. Plus, if you didn't get something done he'd say "Well that's O.K.," and like he wouldn't make a thing out of it if you didn't have it done. As long as you had most of it done then that was O.K. We wouldn't get our notebooks checked or anything; we would just get tests in grade 8.

Student 2: I found grade 8 pretty easy and I didn't have much trouble with it. Just studying was the hard part because he wanted definitions and diagrams. I think the hardest thing about grade 9 science that I've found so far is not so much the hardness of the work, it's the amount of it.

Student 3: In grade 8 science you could just do anything, eh? Grade 8 science was mostly what the teacher does and grade 9 science is mostly up to the individual.

Student 4: More work. More detail. More responsibility. You have to understand. This is more detailed, he explains more and it's more work. . . . In ways it's better because you learn a lot more.

Student 5: We do much more work and it's more concentrated and you have to do it in a certain amount of time. It's faster. It's much more interesting.

V. Junior Secondary Science at Northend School

P. James Gaskell

Northend Secondary School is a large urban school in the lower mainland of British Columbia encompassing grades 8 to 12. This case study concentrates on the junior secondary science program (grades 8, 9 and 10).* The focus on the junior secondary program stems in part from the concern expressed in the 1978 *British Columbia Science Assessment Summary Report*[1] that a large proportion of students avoid science courses in grades 11 and 12 after completing the junior secondary program. A key recommendation of the report was that a major revision of the junior secondary science program be carried out.

This study is not an evaluation of the junior secondary program at Northend. No achievement data were collected; no judgements are made about the aims of the program. The study seeks to describe what is provided for the students and to convey a sense of the context in which the program operates. It looks at the context from the teacher's point of view and describes some of the institutional and social influences on the program. It emphasizes what is common among teachers rather than what is specific to particular individuals.

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*The author gratefully acknowledges the assistance of Gaalen Erickson in developing the proposal for this study and in selecting the site.

Northend School

Northend School is located in a densely populated, largely working-class area close to commercial-industrial facilities. In contrast to other districts, the north end is an area where the inhabitants tend to be less affluent and to have less formal education. They also tend not to have English as their first language. In general, housing prices are lower, housing densities are higher and community facilities such as parks, day-care centres, libraries and hospitals are fewer.

The community contains a mixture of ethnic groups. The duration of a family's residence in Canada varies from a few days to a lifetime. Approximately 60 per cent of the student population speaks a language other than English at home. The relationship of the school to the community is summarized in the school's latest external evaluation report:

> "In summary, the school is well thought of in the community because of its diverse educational program, varied communication procedures, outreach into the community through student groups in choirs, bands, drama productions and 'Community Recreation 12' projects, and positive reaction to complaints. In addition, the school's efforts to increase involvement in the School/Community Committee appear to have developed a small but strong parent voice, which is extremely supportive. Another significant indication of community support for the school is the fact that a number of scholarships and bursaries are provided by individuals as well as by organizations in the community."

Part of the school building is over 50 years old. A major wing was added about 20 years ago. Most of the science labs are in the newer part. Although the school's enrolment is declining slowly (from 2300 to 1700 over the last few years), the school is crowded, and several portables are still in use.

Northend School operates on a semester system in which most courses run for half a school year. A class meets each day for 57 minutes. Teachers teach four blocks out of five each day. Whereas courses in an unsemestered system are based on 120 hours of class time, courses in a semestered system have about 95 hours available to them. (The important implications of this fact for the science program are discussed later.) The semester system does, however, allow for a wide range of courses and electives for the students. Approximately 200 different courses are listed in the school's course description booklet.

Although the students are not streamed, the designation "modified" is applied to one of the five grade 8 classes, one of the six grade 9 classes and one of the four grade 10 classes in general science. Students are timetabled into sections by a computer.

The relationship between teachers and students can be characterized generally as one of mutual respect. As one science teacher commented during an informal conversation between classes:

"Kids here are good, especially if you treat them with respect. Some teachers expect the worst, treat them terribly and then wonder why their cars are vandalized and they are given a harsh time."

Teachers who do expect the worst from the students would appear to be a small minority. In my conversations with a wide variety of teachers at lunch time and during my observations of science classes, I did not encounter any such teachers. There were moments of frustration but no expressions of hostility.

The positive atmosphere of the school in general was apparent in a number of ways during observation in science classes. One was the willingness of teachers to leave students to get on with their work while the teachers momentarily left the room. For example, during an observation of Mr. Daley's modified class, we went into his prep room to talk once the students had begun to work on their own, and later Mr. Daley went to the office to get some duplicating done. Similarly, Mr. Green talked to me in his prep room with the door closed for most of one class period while his students worked quietly on their own. In general, the teachers do not feel they have to stand over their students all the time and badger them to get their work done or to behave properly. The development of trust is worked at consciously. Risks are taken by teachers in this process and there are dilemmas. The tension was perhaps best expressed by Mr. Foley while we made our way to the teachers' lunchroom during the morning break. He had left the classroom door unlocked so that students could go in and out. "I don't lock my door, but I don't like to leave it like that for long, especially with animals in it. You never know what someone might do to one of the frogs. But basically the kids are good." This comment expresses the tension between trusting the students and worrying about the consequences of an incident that might happen because a few students might "lapse."

It was not possible to compare the students in Northend School directly with those in schools in more affluent areas. One teacher who recently moved to Northend from a more affluent area summed up the difference in the following way:

"Of the people I know who have taught in both systems, I consistently hear them say how much more down to earth and honest, albeit perhaps loud and not knowing they are rude, these kids are here. They don't play a lot of the little games some of the more sophisticated kids play. They are more upfront about practically everything. They get very much more attached to you here. The things they will come in and talk about and tell you about either just before school or after are something I have never experienced anywhere else but here. I feel I get my little ears full of all kinds of things that I find even rather shocking."

Mr. Arnold summed up his feelings towards the students from the community in the following way: "I like the kids in this end of town. They're rough. Like rough diamonds they need polishing."

Although teachers respect and like the students at Northend, they recognize that the background of many of the students presents special difficulties. The most common problem is language. Difficulties with English are experienced by Canadian-born children as well as by recent immigrants. Mr. Foley put it this way:

"Kids here don't have the background skills that kids in other schools have. Their written work and the way they express themselves are really fairly poor, and this includes Canadian-born kids."

Mr. Barnes talked explicitly about the problem of children who probably understand the concepts but cannot convey that understanding in English:

"Kids' backgrounds are very variable, and there has been a change in the last few years. There are now a lot of students who don't speak English very well. Kids from Hong Kong have taken a lot of science, but they can't speak English."

Aside from the question of language, the less affluent character of the community creates added pressures for particular students. One teacher commented that it is rare for a grade 12 student at Northend not to have an outside job. A special education teacher mentioned at lunch that there are several cases of students who, because of particular family situations, bring younger siblings to school to care for them. As shown in Table V.1, the percentage of students graduating from Northend in 1981 who went on to community college or university (37.5 per cent) was slightly below the city average (44.6 per cent) and sharply below the figures for a school of comparable size in a more affluent area (66.2 per cent).

Table V.1 – Percentage of 1981 Graduates Enrolled in Community College or University in the Fall of 1981

	Community College	University	Total
Northend	19.1	18.4	37.5
City average	20.4	24.2	44.6
Comparable size school in more affluent area	27.0	39.2	66.2

In sum, there is an overall atmosphere of mutual respect between teachers and students at Northend. The students, who come from an ethnically diverse, generally working-class community, have difficulties in school that tend to reflect the character of the community. They use English less fluently, and more often have to cope with circumstances resulting from financial pressures. They are less likely than students from schools in more affluent areas to go on to higher education. Although life at Northend runs relatively smoothly, it is not without its idiosyncrasies (such as the soap bubbles that regularly overflowed from the sink in one lab as the home economics class above it started their dishwashers), or its moments of alarm (such as the time when a firecracker was rolled under a science teacher's door while the room was blacked out for a movie). Such isolated events can be found in most schools, and coping with them is part of the job of teaching.

Teaching Science at Northend

A Northend science teacher teaches four 57-minute science lessons five days a week for approximately 37 weeks a year. Each day of the semester, the same group of 30 students comes in at the same time. Each teacher has a spare period at the same time each day. There is a routine to the job of teaching, but it is a routine of hard, intellectual and emotional work. The formal routine of the timetable acts as a reminder of the daily pressures to prepare materials, mark books and manage interactions with a diverse collection of willing and unwilling students. The working conditions of teachers act as an important constraint on what is provided to students. Mr. Foley expressed it well:

> "When I look at it overall, I think there is a lot of good talk until you're in the classroom with the kids in your cramped space, in your cramped time with the age group that you've got. It is not an easy thing to translate all the pretty things you hear and all the good theories."

The following section describes some of the job pressures Northend science teachers experience.

Marking and Preparation

The junior secondary science courses are built around labs. Under the constraints of the semester system, not every lab is done, but on average there are about three a week per class. As one teacher remarked, this creates a very severe marking and preparation load. "It's a headache for most teachers but that goes with the job." Different teachers create different solutions to the problem of too much marking. Some skim the books to make sure they are complete and only occasionally check in detail. One stresses the presentation of reports by checking whether headings are underlined appropriately and diagrams labelled as directed. Another concentrates on giving detailed comments to one or two classes for a period of time and then switches attention to another class.

In addition to marking lab reports, teachers must mark quizzes, tests and homework assignments. In a semestered system, there are two reporting periods each semester, as opposed to three reports in a year in an unsemestered system. The physical production of report cards takes a great deal of time. The apparently simple need to enter a mark on a report card directs the teacher to create tests and assignments that will produce such marks.

The pressure of lab preparation parallels that of marking. As Mr. Arnold explained, "When you have four labs a day, it is a lot to keep organized." Locating and organizing equipment for the labs is a constant process of "search and negotiation" for most of the science teachers. Searching is necessary because not all equipment is housed in a central storeroom; much of it is stored in the separate laboratories. Negotiation is necessary because some teachers feel possessive about the equipment stored in their labs. Negotiation is also necessary to avoid conflicting demands for simultaneous use of a single set of equipment. Organizing equipment is harder for the junior secondary general science teachers because five of them teach in five different rooms. At the senior level, where the courses are split into physics, chemistry and biology, one teacher teaches all sections of a particular course at a grade level. Thus, if a teacher accumulates the equipment for Physics 11 in his or her lab, there is no demand for it from other teachers.

The special demands of marking and preparation encountered by junior secondary science teachers are recognized by Mr. Daley, one of the senior science teachers, who also teaches some junior science:

> "I enjoy thoroughly teaching Science 9. I enjoy thoroughly teaching Science 10. Part of that is because I don't teach it every single semester. If I taught it every single semester I think I would find it hard. Particularly the marking is very, very heavy. The lab preparations are very heavy too."

Covering the Material

Marking and preparation create time pressures for the teachers and, in response, the teachers create strategies for managing those pressures. Teachers also expressed a different sort of time pressure, one of rushing to cover the material in the time available. In talking about the time constraints operating against the inclusion of new material relating science to everyday life, Mr. Barnes said, "I feel very pushed for time all the time. Just having 95 hours, it's very difficult to get through everything you would like to get through." A major contributor to this rushed feeling is the time constraint imposed by the semester system. The advantage of increased preparation time under the semester system is offset by the pressure it creates on teachers in the classroom to cover material quickly. Mr. Barnes expressed these mixed feelings when he talked about a possible return to an unsemestered system:

> "We would have more time for the courses. We'd have 120 instead of 95 hours. There would be less pressure on us. Now it seems like we're teaching two years in one and it's really a strain. But the whole problem of losing preparation time is the main disadvantage, I think."

Mr. Cole expressed a similar pressure when talking about teaching the grade 10 chemistry unit:

"I think chemistry is important, but when I've finished chemistry, I feel they haven't really learned it too well. But I have to go on; I have to do another unit. If I had 10 months I'd spend more time on it."

Mr. Foley's "gut reaction" to returning to an unsemestered system was, "If it will slow things down a bit, get rid of it [the semestered system]." He went on to talk about some of the changes that might come with more hours:

"I think there are a lot of things you could do in 30 hours, such as field trips, such as guests coming in, such as just stopping for an entire week and saying, 'All right, we are not going to look at the texts; we're going to do something related to interdisciplinary issues.'"

Even though the department as a whole has agreed on what material should be emphasized and what can be ignored given the time constraints, the junior secondary science teachers still feel rushed. The sources of this pressure are varied. Provincial assessment programs and school board competency tests create pressures to prepare Northend students to the same standard as students in nonsemestered schools. Internal pressures to give students as much of an introduction to science as possible, and a feeling that government guidelines should be followed, also contribute to the sense of strain.

Coping with Kids

The stress of teaching junior secondary students does not come just from the daily demands of organizing labs, marking, and getting through the course. The stress also comes from the demands of teaching children in that particular age group for whom science is a compulsory subject. When asked how he would compare teaching in the junior secondary grades to teaching in the senior grades, Mr. Barnes gave this reply:

"It's probably harder to teach the juniors. You don't have the discipline problems generally to worry about in the senior grades. They're more interested, and they're taking the courses because they want to rather than because they have to, so it's easier to teach the seniors than it is to teach the juniors."

Mr. Foley expressed similar sentiments:

"So junior high to me is a really special time because the kids have no choice, and it immediately gives you a group of little people for whom you've really got to bend over even further backwards. It's not like the 11s and 12s who have chosen it, who are somewhat interested. They're more mature anyway. If they hate it, they will persevere or have more discipline, or think ahead that they need it, or won't be as rude. . . . When you look at your kids up to grade 10, that's a really critical time. If you really turn them off, if they hate

> it, if you bug them, if you don't understand their needs, what their hormones are doing right now, I mean they're out. Kids at that grade level, 9 and 10, it's a time when you either lose them completely or else something amazing can be happening. . . . It's such an in-between, baby years and grownup years, it's a really important age, and I think people should have them a bit and move on. I don't think you ought to grow old teaching that age group because I think you grow stale. . . . You have to bring to it a level of interest and excitement which can be very exhausting."

The extra energy needed to teach junior secondary science was acknowledged in a conversation between two of the older teachers who teach senior grades most of the time:

Evans: I most enjoy teaching the grade 8s because they are the fun kids. They have the most enthusiasm in the school and it gets less and less.

Daley: I'm getting too old for grade 8s.

Evans: In another four or five years probably I'll be getting too old for them.

Daley: First thing in the morning, yes. Last period in the afternoon, no.

Teaching is increasingly acknowledged as being a stressful job. The evidence from interviews and observations in this case study suggest that the job of teaching junior secondary science is especially demanding. This conclusion is consistent with the *British Columbia Science Assessment Summary Report,* which found more dissatisfaction among junior secondary teachers than among either elementary or senior secondary teachers.

Career Stability

Given the pressures of teaching, it is interesting to note that most of the teachers in the science department have been teaching in the school for a long time. Three teachers have been teaching in the school since they began teaching — one 23 years ago, one 13 years ago and one 12 years ago. Two other teachers have also spent a long time in the school, although they previously taught elsewhere. (One has spent 17 years of a 31-year career in the school and the other, 16 years of a 21-year career.) Only two science teachers are relatively new to the school. One has been at Northend for three years and the other is in the first year. The career stability of Northend science teachers suggests that there are some advantages to staying at the school. It is likely that opportunities for transfers would have arisen over the years if individual teachers had wanted to move. Teachers' jobs are centred on their interactions with students, parents and colleagues. Career stability is related to the extent to which there are problems in any of these areas.[2] The attitude of the teachers towards the students suggests that interaction with the students at Northend, while exhausting, is no worse than it is elsewhere and in some ways is better because the students are more open and honest. There are some advantages to staying in the school, in terms of interaction with parents and colleagues.

Parents

One of the advantages of working at Northend, in terms of job stress, is the lack of pressure from parents. Comments from interviews illustrate this fact:

Evans: There is very little parental pressure in this school anywhere. It occurs every once in a while, but as a wholehearted pressure, no. . . . I think teachers in this school, just because they are teachers, are more respected by members of the community because they hold education in a higher plane than most. . . . The teacher does know best, and it is not the parents' job to interfere.

Barnes: Parents couldn't care less. On parents' night I had no one show up out of a potential 120.

This latter comment illustrates some of the ambivalence teachers feel towards the lack of parental involvement. It may be less stressful to have parents at a distance but it is also frustrating when, for professional reasons, teachers want to meet parents to talk about their children.

The contrast between teachers' experiences with parents at Northend and with parents in more affluent areas is illustrated in the following comments:

Daley: Parents here send their kids to school and say, "We assume the school is going to do a proper job with our kids," and that's that. Again, it is very different from the other side of town where my son has just been through school. I personally have been to the principal there several times about this and that, and I have phoned his teachers and talked to them about this and that. Whereas here, in 16 years maybe once or twice I have been contacted by a parent.

Gaskell: Would you like to have the parents here come to you with the same kinds of concerns and pressures as you put on your son's teachers?

Daley: Concerns yes, pressures no. I'm not too sure how I would like it teaching there, putting up with people like myself.

Another teacher (Mr. Foley) characterized parents' attitudes with this comment:

> "This is the first school I have ever been where a parent hasn't phoned me. In schools on the other side of the city, parents would be on the phone right away about all kinds of things."

The issue of parental involvement is particularly interesting at Northend because the majority of students will not go on to post-secondary institutions. It could be argued that students going directly into the job market have different curricular needs than students preparing for further academic courses. Mr. Daley, for instance, implicitly accepts this argument in his answer to a question about what is important to him as a junior secondary science teacher:

> "Certainly the content is important, but when you are teaching a junior secondary class you are not trying to train all of them to be little physicists or biologists. You're trying to show them a little bit more about science and its importance to an ordinary person who is going to go out, perhaps a few years later, into the job market. At the same time, you have got kids in the room who are going to go on and go to university and possibly take a science degree, so you have to have an awareness that you are doing both these jobs."

However, in the absence of any consistent community pressure to define and provide a different science education for students going directly into the job market, the major emphasis in Northend science teaching is preparation for future academic course work.

Colleagues and Equipment

Career stability tends to increase a teacher's control over working conditions, particularly in terms of getting responsibility for desirable courses and access to equipment. In answer to a question about how it is determined who teaches what, Mr. Evans made this comment:

> "Basically, the 11 and 12 program has been set as to who teaches what, and that is historical, not necessarily by seniority. Now, more or less because we three have been here for so long, we have become known as the triumvirate by some members around here."

In my experience, science teachers with university degrees in science (which all Northend science teachers have) usually enjoy their subject. They enjoy telling people about it and getting students excited about it. It is easier to get those subject-matter rewards in the senior grades.

A science teacher new to the school expressed a strong feeling of wanting access to teaching in the senior grades:

> "It should not be a matter of working your way up. I would not stay very long where I felt I had to relate to just one age group. Everyone should have a kick at the can at grade 11."

The reason given for this view is that teaching the higher grades is an important element in maintaining a personal interest in the subject:

> "I am interested in my field and I would really like to delve into it and I am excited about it and I don't want that beat out of me. One of the quickest ways to beat it out is to teach only grade 8 and 9 science for 10 more years."

While seniority at Northend will not guarantee control over courses taught, it does increase leverage in negotiations.

In science, ready access to equipment is a must if labs are to go smoothly. People who have taught for a long time in the school have a greater opportunity to organize equipment to their advantage. A conversation with two of the "triumvirate" illustrates this point:

Daley: Evans and I are crusty old fossils and have been around a long time and made sure we have what we need.

Evans: Between the two of us we are equipped to teach everything, and we keep it that way.

Daley: If somebody starts nosing around after our equipment, to some people we'll say, "No, we haven't got it" and we actually have. That's just a question of self-preservation and previous experience. We know that if this person took this equipment away, when it came back it would not be in the same condition it left. Parts would be lost, *if* it came back. We are just plain miserable when it comes to equipment.

One of the problems of the newcomer is finding out what is tucked away in different storerooms around the school. For a newcomer there is virtually no permanent lab equipment in the classroom. Everything has to be searched for and negotiated.

The process of search and negotiation is made difficult by the absence of architectural or institutional arrangements for bringing the science teachers together on a regular basis. In general, the science department acts as a series of isolated small groups or individuals working alone. One of my regular interview questions was, "Do teachers in the science department work independently for the most part, or do they work closely with other teachers in some way?" Typical of the answers are the following:

Barnes: We generally work independently.

Arnold: I communicate with Mr. Cole next door but there is not extensive communication in the department. I never talk to the people downstairs about their program. It is like two whole different groups, those downstairs and us up here.

Evans: Two of us work together well. One thing lacking in the department is a sense of working together.

One teacher disagreed with his colleagues. He felt the department worked very closely together and that it was the tightest department in the school.

Marking, preparation, covering material and coping with kids mean that teaching science at Northend is hard work. Over time, teachers can reduce some of the pressures by gaining more control over the courses they teach and more access to the equipment they need. Patterns of survival are established. If large schemes for change in science teaching are to make any headway, they must take into account the lives of teachers in schools and the efforts of teachers to make an open-ended workload manageable. This is not to say that innovation cannot or does not take place. Teachers at Northend do work to improve the program by making appropriate changes. But there are limits to the extent of change that can take place without large-scale reorganization of patterns of survival that have been established.

The Curriculum

The science program that is provided for the junior secondary students at Northend is largely determined by the prescribed textbook for each grade.[3] At each grade level the same textbook is used throughout the province. Each of the three books was written by a team of British Columbia science teachers, and each was written to correspond to the most recent science curriculum guide published by the Ministry of Education. The grade 8 and 9 texts have undergone recent revisions (in 1977 and 1979 respectively), but the current grade 10 text is still in its original 1970 form. The three texts reflect the emphasis that the curriculum reform movement of the 1960s placed on developing knowledge through laboratory work. The original 1970 texts, in fact, contained little descriptive text material; they were mainly a series of instructions for carrying out experiments. The recent revisions embed the experiments within descriptive material on the topic under study. The following section describes the kind of science that is taught at Northend, looks at its relationship to the students' lives and gives examples of some of the ways the science teachers adapt material to suit their particular circumstances.

Using the Textbook

The way in which the textbook can shape the science lesson was illustrated in one of the first lessons observed. It was a grade 9 class in the middle of a nutrition unit. On the board was the following information:

4-22 Testing for Fats

Aim: To learn a practical way of testing for fats without using chemicals.
Method: p. 535
Part I (steps A-D)
Do questions 1-5 at end.

At the front of the room on top of the raised demonstration counter were supplies of starch, glucose, oil, egg white and bits cut from brown paper bags. The teacher's introduction went as follows:

> "The stuff that you need is where you found it last day. The egg white is in the same corner; the glucose is in the same spot; oil is in

the corner; starch is in the same corner. Every table has a lamp. You don't have to use it.

"For the lab, the only thing that you are going to need other than egg white, oil, glucose and starch is a piece of unglazed brown paper.

"What I am going to say is absolutely nothing more. How about if I say 'That is it.' It's 4-22, the test for fats. If you want help with an aim there it is, but don't feel you have to use that one. We're doing part I only. The questions assigned at the end are 1 to 5. When you are done and you are tidied up, over on the left-hand side are two sections. I don't really think you'll want to call that homework because the lab is quite quick and when it is finished how about continuing on with that.

"Have a nice lab."

A fair amount of bustle ensued as the students went up to collect their materials and then settled down to do the lab. The teacher moved about the room handing back lab reports and spending a little time with each student, going over the report. In the process, the criteria for a good write-up were reinforced. There was an emphasis on communicating in a clear, logical manner in enough detail that someone else could repeat the lab. The work that they were to do on completion of the lab was defined as follows:

Read 4-21, "Fats," on pages 533-34.
Questions 1, 4, 6, 7 on page 535.
Read 4-23, "Protein," on pages 537-38.
Questions 1, 2, 6 on page 538.

This assignment is interesting because the reading sections were interrupted by the pages describing the day's lab assignment. The questions based on the readings ("The Chemistry of Fats" and "Fats in Your Diet") were taken up the day following the lab on "Testing for Fat." This arrangement illustrates the relationship between the lab and the reading: one is not in a logical relationship to the other. They are about the same topic, but the lab neither flows from questions raised in the reading nor feeds data back into questions raised in the next section. The lab simply develops a testing technique for fats.

The questions at the end of the reading section require, for the most part, a repetition of sentences from the text. Thus question number 1, "What elements are fats made from?" is answered in the first sentence of the text: "Fats are made from exactly the same elements as carbohydrates (carbon, hydrogen and oxygen)." A view of the questions as being straightforward, low-level, recall questions mainly designed to ensure that the text has been read was reflected in comments the teacher made to the class the following day when the questions were taken up. The class discussion of the questions went quite slowly. Finding people with answers to the second assigned question, "Name the two main groups of fats and give an example of a fat from each group," seemed particularly hard. Somewhat frustrated, the teacher responded in the following way:

> "Do you know what I'm gathering from this? That you're reading the question and you're not answering it too fully because I think a lot of people put down what it was and didn't give examples; and what concerns me, I guess, with what you did is that this kind of thing is pretty straightforward from the reading. We should just really check answers, see that everything is O.K. and get on to the lab. We really don't want to spend a whole lot of time on things that you really should have done quite carefully yourself. So, if you are looking at page 534, in great huge bold orange print where it says 'Saturated Fats' and 'Unsaturated Fats,' it explains where they come from and it gives examples."

There is a stress on learning the products of science, on mastering laboratory techniques and tests and on finding correct answers, a pattern described by Roberts as a "correct explanations" curriculum emphasis.[4] This emphasis was common in all grades and for all teachers. The differences among teachers centred on differences of style, and, in particular, on the style of a teacher's interactions with the students. The more informal style of the teacher described above (illustrated by the comment at the end of the instructions, "Have a nice lab") was the exception rather than the rule.

The emphasis on correct explanations flows directly from the textbook and its structure and layout. The questions at the end of the lab exercises seem designed to ensure that a correct explanation of the phenomena has been obtained. The questions at the end of the reading sections seem designed to ensure that the scientific information given in the text has been retained. The grade 10 book has lab procedures mainly, with little text material, and teachers compensate by providing appropriate explanations. For example, in a grade 10 class on microorganisms, the teacher began with a lengthy note-taking activity. He wrote the notes on the overhead projector as the students copied them into their books. The notes contained the scientific knowledge the students were to know, as illustrated by the first sentence:

> "The basic unicellular organism contains all the same cell structures that the basic specialized animal or plant cell contains (nucleus, mitochondria, Golgi bodies, endoplasmic reticulum, etc.)."

Although this teacher probably gives the students more detailed information than do other teachers, the basic pattern of the lessons is the same — presentation of background scientific knowledge followed by an illustrative lab.

Laboratory Exercises

The purpose of the labs is to offer demonstrations of principles of science, to practise procedures and to become familiar with particular pieces of equipment. This point of view was emphasized in a meeting with a school board team that was conducting a survey of laboratory facilities. At this meeting, a team member asked whether the courses were student-oriented or teacher-oriented. A senior teacher responded that they were teacher-oriented. In response to a question as to whether they were lab-centred or demonstration-centred, the same teacher gave the following answer:

> "Oh, it's lab-centred. I believe in process — the process of learning to handle equipment. For example, how are you going to organize ticker tape so that you can use it? Discovery stuff is unreasonable. You can't expect them to discover stuff it took the best minds to discover. Not without some help."

Another way of looking at the purpose of the labs is to observe what happens when things go wrong, when procedures do not work out. One such instance happened during the lab on testing for proteins:

Student (to teacher): Please come here. Nothing happened with our egg white.

Teacher: Report what you found. But it does seem a little strange. Compare it with your neighbour's. In your conclusions, speculate a little bit. Report what you found but say it is different from your neighbour's and that it is a little strange because egg white is protein. You can indicate that maybe your method got fouled up.

This episode points up an interesting tension between, on the one hand, maintaining a pretence that this actually is an "inquiry" and that therefore the student's observation might be what "actually happens" when you add nitric acid to protein; and, on the other hand, the full knowledge on the part of the student and the teacher that what happened ought not to have happened. This is not an inquiry; it is practice at testing, an exercise in learning part of the craft of science — certainly a legitimate aim in itself. The book makes it clear that the student's result is not correct. In the section on procedure the book states the following:

> "(e) Remove the test tubes from the water and stand them in the rack. What does nitric acid do to protein? *What does nitric acid do to the other kinds of food?*
>
> (f) When the test tubes have cooled, add 2 cm of ammonium hydroxide to the egg white. *What does ammonium hydroxide do to protein that has already turned yellow in nitric acid?*" [emphasis in original][5]

It is obvious from the last procedure that, at the very least, the egg white should have turned yellow in the nitric acid.

In a grade 8 class that was doing a lab on light reflection using ray boxes, the teacher made it clear that the data-gathering from the ray boxes was again a demonstration of a known law. The students drew, on graph paper, lines that traced the paths of light rays as they impinged on, and reflected from, a mirror. The final "good" diagram, however, was not based on the actual data gathered in the course of the lab. The teacher handed out a clean sheet of graph paper and said:

> "I want you to do a diagram without the ray box rays on this, just for the sake of labelling it. The diagram is on page 271. Label it the same way it is labelled there."

The diagram on page 271 makes it clear that a textbook mirror produces angles of incidence and angles of reflection that are identical.

In a later lesson on the path of rays through convex and concave lenses it was interesting to observe students who had finished the official experiment early. I watched as one student played with the two lenses (one concave, one convex). He put them together and saw that each cancelled the effect of the other. He moved them about intently, testing the effect on the rays of the distance between the two lenses and the closeness of the lenses to the ray box. As the teacher approached, the student asked, "Is this right? Are they supposed to go straight if you put them together?" This example shows the possibility for more complex exploration above and beyond the formal objective of drawing a diagram. As I moved around the class I observed at least two other groups engaged in the same activity.

The Curriculum and the Student

Student: Can you tell me what we're learning science for?

Gaskell: You tell me.

Student: I don't know. It's not going to come in handy. If you're going to be a mechanic, you don't need to learn about the moon.

* * *

Student: If I see another ray box, I'll die.

* * *

Gaskell: What stands out for you about your science program this year?

Student: The biology section. It can teach you what to do to make you healthy and not to damage your organs. For example, if you eat too much vitamin C it might damage your kidney and some other parts.

In general, the course material is not seen to have any intrinsic interest for the students, although there are exceptions. In a grade 10 biology class I observed a lab in which the students typed their own blood.

The students were obviously involved and interested in the lab. Many of them seemed to have a hard time accepting that there was not a right answer or a preferred type. Students asked several questions of the sort, "I'm type A; is that bad or good?" and "Sir, is there something wrong with being AB?" One student excitedly exclaimed, "I don't have any antibodies! I don't have any antibodies!" giving the impression that this was clearly a result to be valued. After the class, I commented that the students seemed to be interested in it. The teacher responded:

> "Yes, it's one of the few labs they do that they actually enjoy. They learn something about themselves. It's not part of the program here, but I've added it. Otherwise the lab on blood doesn't make much sense. They would be just looking at animal cells and not their own. The lab is actually a Biology 11 and Human Biology 11 lab but I asked the department head and he said it was O.K. if I did it here."

This statement points out a number of issues. First, most labs are not seen to have intrinsic interest; as a result, teachers must adapt the course materials to create interest. Second, teachers must show sensitivity when using labs that are a part of the next year's course. Third, the way to create interest is to have students learn something about themselves.

Not all students, of course, respond in the same way. In most classes there are some students involved in what they are doing and interested in the intellectual challenge. In the lab on unicellular organisms, for instance, one group of students came prepared with a book from the library called *Life in a Drop of Water*. One student in particular talked knowledgeably about what he saw and was respected for that by his friends.

By and large, however, teachers find it hard to engage the students intellectually. Even going over rote questions is difficult, as noted earlier. Labs, however, are easier. Students can talk about a variety of social things while working through clearly laid out steps that require little thinking. Occasionally, teachers try to develop a discussion, but there is little reward in it and it is easier to get it over with and get on to the lab. This situation was sharply illustrated in a grade 8 class in which a film on the boyhood of Edison was shown. In the discussion after the film, the teacher tried to introduce a number of issues "relevant" to the students. The teacher observed how Edison was belittled by his father and other adults, and then asked the students, "Is that something adults do to kids?" After a comment on how Edison's mother was important to his development, the teacher asked, "Did it have to be his mother? Could it have been his father, aunt, hanger-on?" But the students had a hard time responding to the large issues and answered in particular and diverting ways, as in the following excerpt from the discussion:

Teacher: Edison felt that school was stifling to the creative spirit. A lot of school is learning how to please teachers, how to pass an exam. You can't set up a lab on a train the way Edison did.

Do you have a feeling this is true? Can you share your thoughts on this?

Student: I think we should do it.

Teacher: What?

Student: Everything.

Student: Was that a real guy?

Teacher: No, an actor playing him.

Here is a teacher who is accepted by everyone, including the students, as competent and caring. Yet the difficulty he has in breaking out of the established pattern of low-level intellectual routine with his class is enormous.

Some units in the curriculum are directly related to students' lives. For example, in the grade 9 unit "Energy and Living Organisms," the relationship between energy and food and the rules for good nutrition and diet based on *Canada's Food Guide* are discussed. I was interested in the extent to which the scientific knowledge presented to the students affected their behaviour outside the classroom. In my initial observations, most of the lessons on nutrition did not appear to be much different from lessons on light rays. They consisted of scientific information to be learned and lab procedures to be worked through. Students needed to know the chemical composition of fats, proteins and carbohydrates, how to test for each, and which foods were examples of the four food groups in *Canada's Food Guide*. However, the teacher also invited a nutritionist to come to the class to make a presentation and answer students' questions about diet.

The visit of the nutritionist indicated some of the difficulties teachers face in integrating "outside experts" into the classroom. In this case, although the nutritionist was well-meaning and well-prepared, her lack of skills in the craft of teaching made her less effective than a teacher in responding to the students. She was less aware of cues, less flexible and had less of a sense of timing. She was not able to build on previous lessons and, as a result, much of her presentation repeated material previously covered in the lesson on *Canada's Food Guide*. Nevertheless, there was some time left for a few questions at the end. The students mostly asked for advice: "What can I eat to get fatter?" or "What foods are good for body-building?"; others asked for explanations: "Why can you only count one serving of potatoes?" and "How come I eat and eat and don't get any fatter even though I put on weight?" Except for the potato question, all the questions came from the personal experience of the students. There was little evidence that bridges were being built between the chemistry of foods and the advice on diet.

In order to gain some evidence of the possible effect of the unit on students, I interviewed a small group of them chosen by the teacher as representative of the range of students in the class. I asked the students what effect the nutrition unit had had on their diet. They gave the following answers:

Student 1: I get out of the room now when my father smokes. I watch what I'm eating more, exercise more and take care of myself more.

Student 2: I got my mom to quit smoking.

Student 3: Everything I eat I check it out. I didn't do this before the unit.

Student 4: I got the idea of looking at the labels and seeing what was in the food.

Student 5: I told my dad to stop smoking and he cut down.

It should be noted that the interview was conducted after a speaker from the Cancer Society had talked to the class about smoking and health. Although I specifically asked about nutrition, three of the five students responded about smoking, which is part of a later unit on respiration. However, students' ways of dividing up the world are not the same as ours. Possibly these students were responding to a wider concept of health rather than to a concept involving compartmentalized systems in the body.

The students' comments obviously cannot be taken as evidence of scientific knowledge having long-term impact on their or their parents' behaviour. Students' control over their own nutrition must be marginal at best, as they are largely dependent on what the family buys for them. Still, the positiveness with which all the students responded is interesting. Student interest in their own health and physiology seems high; however, the kind of knowledge that best reflects this interest is unclear. When the ingredients are listed on a food package, you don't need to know the test for sugar to test your food. Junior secondary students are not going to be able to judge the merits of nutritional advice they are receiving and will have to rely on the authority of experts chosen by their teachers. Students are more likely to respond to general rules of thumb. The structure of protein and the test for fats will remain isolated academic exercises. The tests done during the blood-typing lab, on the other hand, are different; in the blood-typing lab the students found out something new about *themselves*. By contrast, there was little doubt in students' minds about the contents of the food they tested.

Teachers try in a variety of ways to relate science to their students' lives. The blood-typing lab is one example; the bringing in of a nutritionist is another. Yet another way of making science relevant involves the use of practical examples, which one teacher used extensively. In discussing light reflection from a mirror, this teacher talked about the construction of periscopes and their use in submarines and in crowds, and he also related reflection to the use of mirrors on a rotating ball to scatter light at a dance. In introducing lenses, he talked about eyeglasses and reminded the students of the necessity of being able to see properly. The classes in which these examples were observed illustrate a point that needs to be kept in mind as pressure to reintroduce practical applications of science increases. Simply including more references to practical applications will have little effect on students if the underlying structure of the curriculum remains unchanged. The real work in this class consisted of doing the labs and learning the science associated with them. The lack of eye contact between teacher and students, the low number of questions asked and the continuous student murmur in this class suggest that practical examples by themselves have little effect on student interest and, by inference, on their understanding.

In response to a specific interview question about their reaction to the possible inclusion of more material with a science and society emphasis, all the teachers expressed support. The suggestion evoked in most teachers recollections of a 1950s-style science curriculum based on *Science in Action.*[6] This approach emphasized the practical applications of science in the everyday world. Teachers want to increase the relevance of science to children's lives provided that the skills needed to do grade 11 and 12 science are not forgotten. Other considerations were expressed as well. Mr. Barnes would like to see more material on the uses of science in Canada and examples of Canadian research. He is concerned about the lack of support for scientific research in Canada and wants to encourage students to vote for people who would support science. Mr. Arnold would like to include topics of current concern such as genetic engineering and energy, believing that it is important to deal with moral issues and to push students into thinking through moral decisions. In addition, he feels that, if students had an idea of the relationship between science and society, the academic material would become more meaningful. Mr. Daley, on the other hand, sees knowledge about science coming first; for example, one has to understand something about chemistry before one can understand how chemistry is important to the fertilizer industry.

Although there is general support among these teachers for a greater focus on science and society, the constraints of time, textbooks and ministry guidelines are mentioned as reasons why teachers cannot include such topics at present. However, some adaptations of the present course to make it work better have taken place.

Course Modifications

Evidence suggests that the science teachers at Northend work conscientiously at improving the programs they offer, but within certain limits. As Mr. Arnold commented:

> "I believe in change. I try to change things all the time except, of course, the basic structure. An atom is an atom."

Teachers work to adapt the material to facilitate students' understanding of it and to accommodate their programs to available resources. However, the basic structure of the curriculum is determined by ministry guidelines and the prescribed textbook remains unchanged. Mr. Arnold and Mr. Evans both mentioned changing the chemistry unit so that valence is not presented in terms of rings and fasteners. Similarly, the gremlin model of electricity that appears in the textbook is ignored. More extensive changes are made to the material developed for the modified classes, for whom a variety of different texts have been tried. At lunch, a special education teacher commented favourably on the work that had gone into developing the modified science program. She contrasted the readability of the science material to that of other subjects in which she would have to put the textbook on tape in order to make it accessible to the students. One of the science teachers described his version of the modified grade 10 program as a personalized adaptation from a number of sources. The sources include a new textbook he has helped to pilot-test, lab sheets he has developed and modifications from other textbooks.

Although this study focusses on the junior high school program, some significant innovations at the senior level are relevant to it. The head of the department has been one of the key people involved in a locally developed course, Human Biology 11. Two other teachers have worked hard to integrate basic computer programming into their science program. This work was finally defeated when the computer terminal was removed from their room and put into the Business Education Department for use in that department's Computer Science 11 and 12 courses.

These examples suggest that the teachers are prepared to put substantial amounts of their time into creating new programs and modifying old ones. It is instructive, however, to recognize some of the constraints on the type of innovation that can take place. For example, in the meeting with the school district facilities team, the issue of moving to a more project-oriented curriculum was brought up. As some teachers pointed out, however, one of the constraints opposing such a move was the lack of available space to store projects between periods. With the school as crowded as it is, there is no extra room available at present to use for this purpose. More interesting than such physical constraints, however, are some broader institutional and value constraints that operate to shape the curriculum in particular ways. If significant change is to take place, the impact of these constraints must be recognized and taken into account.

Influences on the Curriculum

The junior secondary science program reflects the influence of a number of institutional and social factors. Of particular interest are the influence of the senior secondary program on the junior secondary program, the influence of the university on the whole of the school science program, and the influence of broad social values on school science.

Senior Secondary Influences

The influence of the senior secondary program is most clearly felt in talking to teachers about how decisions are made about what to emphasize and what to leave out, given the time constraints of the semester system. There is general agreement that what is emphasized at the junior grades is what is considered to be the best preparation for work in the senior grades. Thus the rationale for the curriculum emphasis on correct explanations is the need to provide a solid foundation for further work. Mr. Evans expressed the justification for the grade 9 focus on chemistry in this way:

> "Each of the teachers teaching senior science have been asked, 'What would you expect a student coming out of grade 10 to have?' We all put our two cents' worth in. Essentially, as I recall from Mr. Daley, he doesn't really require that much in physics coming out of grade 10. He feels that the way physics is approached in 9 and 10 is totally backwards and has no bearing on what would take place in 11 or 12. As long as the student is academically competent, he feels he can get enough in 11 or 12. Whereas, I feel with the chemistry that there are certain fundamental skills a student must have that we don't have the time to teach in either 11 or 12; for example, balancing equations, computing molecular mass, understanding formulae, knowing what the subscripts mean, what coefficients mean in front of formulae in an equation, basic understanding of the periodicity of the table of the elements."

The science department head explained that the earth science unit is not taught because it is not needed for preparation for a next course. At Northend, the new courses in Earth Science 11 and Geology 12 are not offered. Mr. Daley reiterated the general department position in his interview:

> "I guess the criteria there is what is going to be most useful to the kid next year in school. Those that are going on to grade 11 science have to be given priority. This bias is because I teach grade 11. If I didn't, perhaps my priorities would be somewhat different."

Interestingly, the only person whose priorities appeared to be different is the new teacher who teaches only junior secondary science and who had not participated in the department meeting where it was decided what to emphasize and de-emphasize. This teacher would prefer to teach some of each unit, rather than a lot of some units and none of others.

In looking at the impact of the senior high expectations on the shaping of the junior high courses, it is important to remember that a senior science course is not currently a requirement for graduation, although it is a requirement for university entrance. For many students, grade 10 science is their last science course.

University Influence

The pressure to prepare students for the next level continues on through the senior grades. There it becomes preparation for university. Thus the university, in a variety of ways, becomes a major influence on the school curriculum. The influence of the university was raised as an important issue at the very first meeting with the teachers. The department head asked this question:

> "Are you commissioned also to look at outside influences and measure their impact in science teaching? For instance, the universities come down on us and can mould the way science goes as they have been doing. That's a very serious impact."

The influence of the university is exerted in two ways. One way is through the teachers who feel that the curriculum must reflect preparation for success at university so that no one is denied the opportunity to succeed, even if only a small number of students actually go on to university. Mr. Cole expressed it this way:

> "Every kid should have the opportunity to go on to university. So we had better give them all the stuff they may need, even if maybe only five per cent go. We want kids to be successful if they go to university."

The second way in which the university influence is felt is more direct. Each year the University of British Columbia (UBC) sends each high school the marks that that school's students obtained in their first-year university courses. The implication appears to be that schools should use these results to evaluate the effectiveness of their programs and standards in terms of preparing students for university.

The university also influences the science program through its acceptance or nonacceptance of courses for credit for university entrance. At Northend, Human Biology 11 has been developed to attract students into a senior biology course. The course is having difficulty surviving, in part because it was not accepted by the universities or other postsecondary institutions as fulfilling the science requirement. Other admission requirements affect the number and variety of science electives that students can reasonably fit into their programs. For example, an examination of data on enrolments in science courses province-wide shows a dramatic decline in 1977-1978 when the university announced it was reinstituting a language requirement for university entrance.[7] More recently, teachers have been concerned that changes in the University of British Columbia's Faculty of Science admission requirement to include a science 12 course will reduce the number of students enrolling in courses such as Earth Science 11. In the past, students going into the Faculty of Science often elected a third Science 11 course in addition to the Physics 11 and Chemistry 11 courses required by the ministry. These students are now replacing that elective with the Science 12 course required for admission to UBC. (The introduction by the Ministry of Education of two new compulsory courses, Consumer Fundamentals and Composition 11, is causing a similar concern about the restriction of electives for students.)

A distinction should be made between preparing students for university and preparing them for scholarship exams. The senior science teachers made it clear that they do not emphasize preparation for scholarship exams, as that involves only a small number of students, two or three a year. Mr. Evans made this comment:

> "I prefer to teach and have them follow the government guidelines religiously so that it prepares every student for university essentially. I wouldn't want to direct all my efforts at scholarships. I would find I would lose two-thirds of the students right out the door quickly."

I inquired about the practical effect of this distinction. He explained that teaching for scholarships is done by analyzing past scholarship examination papers and emphasizing those topics and types of problems that have appeared most frequently. "It's quite evident what to do and what not to do." However, in May he does get together with scholarship students and go over problems with them separately. This procedure contrasts with that followed in schools in more affluent areas of the city where the teaching is heavily influenced by scholarship preparation.

Influence of Social Values

The pressure for university preparation does not come explicitly from Northend parents. As explained earlier, there appears to be an insignificant amount of parental pressure exerted on the science teachers. Where, then, does the pressure to prepare students for university come from, given that less than half of all Northend students go on to university?

One answer is that the pressure comes from a fundamental value position of the teachers. It is expressed as a responsibility to those who will succeed, with success being defined as doing well at university. For example, Mr. Daley spoke to me about introducing the applications of science to the modified classes. When I asked him if he felt that that approach would be more appropriate for modified classes, he made these comments:

Daley: No. No, I think it would be just as appropriate obviously for anybody, except that we have to teach them chemistry and physics, electricity and stuff, and so we can't. . . we don't have time to. . .

Gaskell: We have to do that because. . .

Daley: I haven't really thought about it. We have to do that because those that are going on have to have this knowledge. They must start to learn balancing an equation, Ohm's law, meiosis and mitosis. They have to learn it somewhere, to start at some point learning the facts. Where do you start?

Gaskell: What it is then, essentially, is the grade above filtering down the expectations.

Daley: Yes. What does society expect a kid coming out of the education system at a particular level to have? The educational system is like a sort of fractionating stack and the products pop out. There's various levels of the stack. . . . So what they teach in Science 9 is a reflection of those expectations.

He went on to say that he feels that the parents at Northend reflect these expectations less than the parents of more affluent students. Thus, whereas this pressure is spoken of as a pressure from "society," it may in fact be pressure from a particular class within society.

Social values are reflected in the curriculum in other ways as well. The notion of what constitutes science, for example, has affected the structure of the curriculum. One issue highlighted in the Science Council's Science and Education Study is the role of technology in science education.[8] Interestingly, there are courses on technology at Northend. They are listed in the course handbook in the industrial education section. At the junior secondary level there are courses such as Electricity 8 and Electronics 9/10 that emphasize practical applications of scientific principles and involve students in project work. The division between academic "pure" science located in the science department and practical technology located in the industrial education department reflects the different status in our society accorded to mental and manual labour. The prevailing view that "pure" science has higher status than "applied" science was at least partly responsible for the opposition of science teachers in England to Project Technology.[9]

Another way in which the curriculum reflects social values is illustrated in the nutrition unit. The emphasis in the unit is on the responsibility of individuals to ensure an adequate diet for themselves, once they are given information on what constitutes an adequate diet and the reasons for it. The students' responsibility is to themselves; for their own good. Thus, nutrition is abstracted from its social content. An alternative, for example, would be to put the topic in the context of an individual's responsibility to the state to remain healthy and the state's responsibility to its citizens to ensure an adequate diet for everyone. In these alternatives, health is not just a scientific and technical product, but a political one as well. The Canadian state has assumed a large measure of responsibility for the provision of health care for its citizens, but this fact does not form part of the context of health education. In East Germany, in contrast, the political dimension is part of the biology curriculum.[10] Science curricula, like other curricula, reflect the political systems in which they are used.

The junior secondary school science curriculum is influenced by institutional and social factors such as pressure from senior secondary teachers, expectations of the universities and dominant social values. Any large-scale attempt to change the curriculum in fundamental ways will have to take account of the close connections between what occurs in schools and the powerful institutions and values that shape the curriculum.

Conclusion

The science education that is provided for the junior secondary students at Northend School is the result of a complex web of factors. A report such as this must necessarily highlight some and downplay or ignore others. The main feature of the curriculum is an emphasis on learning correct explanations for a variety of phenomena that are seen as important to science as a discipline. The major purpose is to provide a solid foundation for further courses in science. Although some attempt is made to break the pattern, it is generally acknowledged that the science content is of little intrinsic interest to the students. Lessons are built around the prescribed textbook, which is designed to follow ministry guidelines.

The extent to which teachers can adapt the material is constrained by their work situation. The main problem is to devise strategies to contain an open-ended job. Teaching junior secondary students is particularly stressful in terms of dealing with the emotional needs of that age group. The rewards of teaching come less from working in an area of academic interest and more from developing personal relationships with students.

Although the major outlines of the course are set by the textbook, teachers make many modifications where their experience has shown them that the textbook approach does not work well. Teachers are open to including more science and society material in their teaching but feel constrained from doing so by pressures of time. These pressures are exacerbated by the shortened course time resulting from the semester system.

In addition to job pressures, changes are also constrained by the relationship of the curriculum to other institutions and social values. The universities' significant influence on the school curriculum is apparent in the priority teachers give to preparation for university. This emphasis reflects the teachers' feeling of special responsibility to those who have the best chance of success, where success is defined as continuing with formal education. The tension between preparing people for university and preparing them for "life" is highlighted at Northend because the majority of its graduating students go directly into the job market. Where the science curriculum touches on people's lives, as in the nutrition unit, there is an emphasis on an individual's responsibility to himself or herself. This is consistent with a political system that stresses individualism in contrast to socialism. The influence of institutional constraints and social values must be taken into account in any effort to alter fundamentally the junior secondary science program.

Notes

1. E.D. Hobbs, W.B. Boldt, G.L. Erickson, T.P. Quelch and G.A. Sieben, *British Columbia Science Assessment Summary Report*, British Columbia Ministry of Education, Victoria, BC, 1978.

2. H.S. Becker, "The Career of the Chicago Public School Teachers," *American Journal of Sociology*, 1952, vol. 57, pp. 470-477.

3. The three textbooks are: M.C. Schmid and M.T. Murphy, eds., *Introducing Science Concepts in the Laboratory*, 2nd edition, Prentice-Hall, Scarborough, Ontario, 1977; M.C. Schmid and M.T. Murphy, eds., *Developing Science Concepts in the Laboratory*, 2nd edition, Prentice-Hall, Scarborough, Ontario, 1979; and M.C. Schmid, ed., *Extending Science Concepts in the Laboratory*, Prentice-Hall, Scarborough, Ontario, 1970.

4. D.A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education," *Science Education*, 1982, vol. 66, no. 2, pp. 243-266.

5. M.C. Schmid and M.T. Murphy, eds., *Developing Science Concepts in the Laboratory*, 2nd edition, Prentice-Hall, Scarborough, Ontario, 1979, p. 540.

6. G. Paterson, *Science in Action*, Dent, Vancouver, BC, 1955.

7. British Columbia Ministry of Education, Statistical Services, *Organization of Secondary School 1980-81*, Publication No. 10, Victoria, BC, 1981.

8. D. George, *An Engineer's View of Science Education*, Science Council of Canada, Discussion Paper D81/2, Ottawa, 1981.

9. B. MacDonald and R. Walker, *Changing the Curriculum*, Open Books, London, 1976.

10. E. Jungwirth, "Science Education and Politics," *Science Education*, 1981, vol. 65, no. 3, pp. 253-258.

VI. Science at Derrick Composite High School

Patricia M. Rowell

This report is based on observations made in the classrooms of seven science teachers over a period of four months. Extended discussions on a one-to-one basis with four of the teachers, in addition to conversations with administrators, provided the opportunity to explore the science classroom from the perspectives of the teachers. My interaction with students in the science classes was minimal, and this study has no claim to represent what it is like to be a student of science at Derrick Composite High School.

Recognizing that the activity labelled as science education occurs in a school setting that is itself part of a much larger and complex societal context, this report is presented in two general sections. The first section provides a description of the situation in which the teachers work: the location of the school and its clientele, their colleagues, the tasks of the school and the organizational framework that fulfills them. These factors contribute to what I shall call the institutional context for science education in this particular high school. These institutional characteristics are a consequence of past and present beliefs that led to the formulation of social demands for certain kinds of education. Consideration of this broader social context which encompasses the institutional features is beyond the scope of this study, although an awareness of the constant interchanges between the two spheres is essential.

The second section of this report attempts to portray the daily activities of teachers who have assumed the responsibility of educating students in science. The beliefs and assumptions on which such activities rest are tentatively explored, in the hope that we may reconstruct the world in which the teachers find themselves, that is, their pedagogical context.

The Institutional Context

Students

Roughly 1600 students, the majority of whom range in age from 15 to 18, attend Derrick Composite High School, which was established in the late 1950s. Soon after 8:00 each morning, students unload from school and city buses, and the parking lots fill with student-driven cars. The school is one of 10 such institutions in an urban school system that maintains an open boundary policy; students may attend the senior high school of their choice. The majority of the students opt for the school established within their residential zone, although between 100 and 200 students travel out of their zones to attend this school.

Located in a district reflecting a broad spectrum of socioeconomic conditions, the school is in the vicinity of an affluent, professional, residential district, in which parental expectations for the education of their offspring are articulated frequently and fluently. These parents purport to be seeking a high school program that will prepare their children for successful entrance to university and other professional programs, by offering a rigorous, intellectual challenge. This parental interest in the securing of credentials is acknowledged by the science department, which states as one of its goals, in the school handbook, that it will "attempt to meet the expectations of parents and students in the preparation of students for further learning institutions." The establishment of substantial provincial scholarships for students accumulating honours standing in grades 10, 11 and 12 has added to the competitive spirit of the educating process. Noted one administrator, "Not only students but parents get involved in the grading system. . . and for scholarship marks you are now competing as of the first grade 10 report card mark." Thus, although discouraged by the administrative staff, students will withdraw from classes in which they are not obtaining sufficiently high marks, in order that they may reregister with another teacher. One teacher reported that, although it is normally students who bargain for marks or arrange course transfers, he has had parents telephone to complain about "the kind of marks he is giving."

The community demonstrates its concern and support for the school by high attendance at "Meet the Teacher" nights. In the last annual survey, 93 per cent of parents polled expressed satisfaction with the performance of the science department, the highest rating in the school. And yet it was pointed out by one teacher that community involvement in terms of the daily activities of the science department is nonexistent, and only minimal interest is generated by the methods or content of science teaching.

Teachers

Eleven of the 60 teachers at Derrick Composite High School are members of the science department. This year, student registrations and timetabling arrangements allow for two teachers of physics, four of chemistry, four of biology and one teacher of chemistry and biology.

The four teachers with whom I had extensive discussions gained their first degrees in science or education at the local university, and have maintained somewhat tenuous links with the university personnel in their fields. One of the teachers completed his MEd degree at a distant university, and another taught overseas for four years, but, in general, the teachers have spent nearly all of their teaching careers in high schools within this particular urban system. Contact with colleagues in other schools occurs intermittently, at provincial and local (teachers' association) science council meetings and during the two days of the annual teachers' convention, but not necessarily during professional development days. Contact with colleagues within the science department of the school is limited to moments snatched between lessons, and the occasional staff meeting. The science staff room, providing office space for all but two of the department members, is seldom occupied by more than two or three teachers at one time. At the beginning and end of the day, there is the opportunity for nothing more than the cursory comment on current events. Hiring practices of the school administrators favour teachers who are prepared to become involved in extracurricular activities such as coaching teams, sponsoring clubs and organizing for the yearbook or graduation.

Mr. Davis arrives in school 15 minutes before the beginning of his first class, and goes directly to the room in which he will spend all but one of the eight class periods of the day. The first students are awaiting his arrival in the hall, and enter the classroom with him as the door is unlocked. They chat informally with Mr. Davis as he prepares for the daily sequence of classes in which he will attempt to interact with 180 individuals, a task which he is finding increasingly frustrating. His first class is the first of four nonstreamed grade 10 groups that he will encounter during the day. He feels badly that he doesn't have the energy to develop the individual relationships with the grade 10 students that he thinks are an important component of school life. He notes that "there is some limit to how much I can reach out." He says that he doesn't try to teach the same sequence of topics to these classes, because of the dreariness of repetition. He will also meet a grade 11 and grade 12 class. Mr. Davis generally spends his one spare period in the staff common room, chatting about current events over a cup of coffee, or completing minor chores. This is the only time he has to himself during the school day, because he devotes his lunch hours to the organization and meetings of a school club. After school, he works with colleagues who are preparing computer programs for school implementation.

Tradition and Task

Students who cross out of their residential zones to attend Derrick Composite High School are, for the most part, those who are attracted by the academic "tradition" associated with the school, a feature frequently referred to by several of the teachers. A senior administrator attributed this so-called tradition to three factors. First, the school offered a very restricted program in its early years: the only alternative to the academic core-plus-science was business education. Second, the first principal recruited a staff whose priority was traditional academic excellence. And third, the expectations of the clientele from professional backgrounds were satisfied by a traditional academic approach. Today, the program is considerably broader, including home economics, industrial arts and drafting, and the same administrator expressed the opinion that it is no longer appropriate to describe either the program offered in the school or the achievement of the students as being distinctively "academic." However, the fact remains that 50 to 60 per cent of the students who graduate from this school proceed to postsecondary institutions, having received the necessary credentials during their three years of attendance. On inquiring about the origins of the statement of school objectives included in the school handbook, I was told that as far as the teachers are concerned, the statement's chief purpose is to satisfy the requirements of the school board. The goals of the school appear to be tacitly shared by its staff, as this teacher had never participated in an open discussion of them. But, he noted, "teachers, even with the best intentions, are concerned only with instruction."

Program Selection and Organization of Classes

Students qualify for a provincial high school diploma if they obtain 100 high school credits, which must include credits for one science course. Matriculation satisfies the basic entrance requirements for university, and requires that students attain an average of 60 per cent on their high school diploma, including credits for five grade 12 courses. During the recruitment of grade 9 students from the eight feeder junior high schools, students are advised to select courses for their senior high school program on the assumption that they will matriculate. The majority of grade 10 students will select two science courses from physics, chemistry or biology (see Appendix A). The program adviser commented, "In accordance with university program selection, you see chemistry as being the core [science] course, and either physics or biology completing the pair. There are no limitations for good students, who may take all three subjects in grades 10 and 11, and then make a selection for grade 12." This advice has resulted in 7 physics classes, 15 biology classes and 16 chemistry classes in the current grade 10, with a similar distribution in grades 11 and 12. Students are assigned to course sections by computer; in the classes observed, there appeared to be a more or less even distribution of boys and girls.

Junior high students who fail grade 9 science are placed automatically into a Science 11 class, a "terminal" course of introductory science units, ostensibly reflecting the "needs and interests of students," but essentially satisfying the diploma requirement for credits in one science course. Students may proceed from Science 11 to Biology 10, Chemistry 10 or Physics 10 if they succeed in passing the course with the teacher's recommendation to continue.

The school year at Derrick consists of two five-month semesters. The grade 10 and 11 courses (three credits per course) are presented in daily, 40-minute classes for one semester, in contrast to the grade 12 courses (five credits) for which the daily 40-minute classes extend over the whole school year. In order to accommodate students who make a late decision to include science in their grade 12 program, one or two semestered courses are offered in which students attend daily 80-minute classes for one semester only.

Students are provided with the opportunity to obtain credits or improve grades for science courses in summer school programs of three to six weeks' duration. The course administrator and the physics and chemistry teachers were quite outspoken about the conceptual difficulties that seem to confront students who advance into senior science courses via the summer school route. Such courses are a prime example of learning for credits: "You are not tested on something you haven't had presented to you, and you can't cover in three weeks what you take in five months, so obviously you're being examined on a narrower sample of material."

Resources

Students are required to purchase the textbooks prescribed for each of their science courses (see Appendix B) – a considerable financial burden for some families. Concern over this fact guided the biology teachers in their decision to use a single text for the grade 10 and 11 courses. Although some teachers favoured retention of the *Biological Sciences Curriculum Study* (*BSCS*) "Green" text for Biology 20 on the grounds of its strength in ecology, other teachers noted that students find the *BSCS* "systems" approach confusing, preferring the factual presentation based on plant and animal classification, as in Otto and Towle (*Modern Biology*). Class sets of supplementary texts (of variable vintage) are available for all the science courses, although they are rarely used in the chemistry courses.

The city school system has an extensive film library from which one-week loans may be requested. However, teachers pursue an individual sequence of instruction, and because a film may be requested only once per semester per school, its arrival in school may be appropriate for only one of the four biology teachers. The other three must then decide whether to "fit in" the film, thus interrupting attention to the topic in hand, or to ignore the film altogether. The former strategy is illustrated in a grade 12 biology class that has commenced an examination of cell transport mechanisms when a film on photosynthesis and respiration arrives in school. The teacher introduces the film:

> "Today I want to interrupt what we've been doing, to take a look at a film on photosynthesis and respiration, because the very next topic that we're going on to is respiration, and the film is here now, and we won't be able to get it back again later. So you should be prepared to make notes; make yourselves a heading on a new page, 'Respiration and Photosynthesis,' and put in brackets, 'film,' so you know where the information came from."

The film, of the 1960s era, was watched passively by most students, who did not take notes. Several private conversations were conducted very discreetly until the conclusion of the film, at which time the teacher commented, "We will be going on to respiration very soon, but right now we'll get back to transport mechanisms." I gained the impression that for students who have grown accustomed to the superb visual effects of *Star Wars* and *Cosmos*, 15-year-old movies are somewhat tame, if not dismal. Perhaps this reaction underlies the attitude of another teacher, who offered this reflection on his occasional use of films:

> "I don't use a film as an instructional tool any more. I used to give a good build-up, have the film, and then a good discussion. Now I tend to use the film as an illustration of what I've been talking about, or as an introduction to a topic."

The school library holds 25 000 books and is staffed by two librarians and two aides. The library budget allocated $17 000 for the acquisition of new books last year. All members of staff are urged to participate in the selection of new materials, although the librarian suggested that the onus lies largely on him to choose titles from catalogue lists. The physics section included titles on astronomy and the earth sciences and in the biology section, a broad range of publications dealt with inventions, acupuncture, genetic politics and evolution.

Many of the features of this institutional context have been inherited from times when teaching was viewed as the transmission of expert knowledge, and learning as the assimilation of the same. Such views are not necessarily taken for granted by the teachers of this school today, but the organizational framework born of these views encompasses the individuals within it. The physical arrangement of classrooms and the characteristics of timetabling limit the possible interactions between teachers and students. One teacher of four daily grade 10 classes expressed the wish to give a single lecture presentation to his grade 10 students, and spend the remainder of his scheduled time in seminar-type groups. This could not be accomplished in the present context, or permitted by current scheduling. Another teacher who recognizes that learning progresses at an individual pace finds himself forced to lockstep his students "simply because of the demands of the rest of the school." He suggested that other course commitments would overrule any time flexibility provided in his classes.

Assessment of Student Performance

Unit tests are administered at the conclusion of each section of each course, and it was not uncommon for students to be tested in the same week that the information was presented to them. An apparent contradiction exists between the teachers' sense of responsibility to equip "their" students for further stages of education by providing a solid foundation, and the necessity to provide a series of numbers representative of short-term recall performance. Many unit tests and all final examinations are composed of multiple-choice items only. (Written assignments are limited to one per course.) The type of questions employed in the unit tests apparently is the cause of some concern for teachers who wish to follow student thinking patterns. Multiple choice items are of no assistance here, but sheer numbers force their use. Remarks one teacher: "I've had to lower my standards [of assessment] because of unusually large classes; I have to use a combination of multiple-choice and problem-solving questions, instead of all problem-solving."

This science department has compiled a bank of multiple-choice questions, although some of these are of questionable value. One teacher made this remark to his grade 12 class:

> "I just want to make a comment about number 5. I like to make my diagrams reasonably accurate; I'm not sure where this diagram came from. I think someone was half asleep when they drew it, or they weren't too concerned with accuracy. But I want you to see that the curve should actually be bimodal; it should have a peak between violet and blue, and another one between orange and red. Even the colours at the bottom are not in the correct order. So it wasn't a very accurate diagram; but the best answer obviously is the one given, even though the lines are not accurate."

Within each discipline area, mark allocations are carefully structured to provide uniformity across class sections. Biology 30 students are provided with a mark sheet that details the allotment of points for up to 15 specified components of a research paper, which is "worth" a maximum of 15 per cent of the course grade. Final examinations (25 per cent of the course grade) are common to all course sections, in response to board and school administrative policies of striving for uniformity of standards. However, teachers acknowledged that it was not unknown for examination questions that related to topics not covered in class to be "cut" from the mark total.

A dominant factor in the determination of this institutional context seems to be the recognition that students need to acquire credentials for further education and training, and this being so, it is the task of the school to provide these effectively and efficiently.

The Pedagogical Context

Underlying the patterns of daily activities and interactions are teachers' assumptions about the nature of knowledge and what it means to be engaged in science education. These assumptions are reflected in teachers' expectations for students and themselves, and in all aspects of teachers' communications to students, communications which in themselves create conceptions of schooling and knowledge. Implicitly or explicitly, science teachers impart messages about science during their daily discourses.

Knowledge and Learning in School Science

The prevailing conception of curriculum as a body of knowledge external to both the learner and the teacher, and embodied in the provincial curriculum guide and prescribed texts, appears to direct most of the school science activities. The teachers demonstrated an unswerving commitment to the course content of the curriculum guides, to the acknowledged neglect of more interpretive aspects of course implementation. Each course is organized into discrete, sequenced units of information, the assimilation of which may be assessed by specific, objective unit tests. The Chemistry 10 course was described to me as being "essentially five units: (1) a descriptive unit about the elements and learning formulae; (2) writing and balancing equations; (3) conversion of gram to molar mass; (4) conversion of molar mass to gram; and (5) combining all the above knowledge." More than one teacher commented favourably on the "cut-and-dried" nature of the chemistry program, which utilizes the *ALCHEM* kits: "You don't have to go running around, looking in different books, and developing your own materials," and "It's fixed, there's only one right answer. Because you don't have to be making decisions about what to include or not to include as content, you are able to conduct a much more spontaneous interaction with the students."

One of the biology teachers has assembled learning packages for every unit of each course; these include a statement of the specific objectives, such as developing students' ability to identify structures, define terms, state concepts or explain the significance of concepts. Also listed in the learning packages are learning activities that will assist students to achieve the specified objectives. Such activities may involve reading the textbook, labelling diagrams, performing laboratory exercises, attending lectures or watching films. The final activity for each unit is the writing of the unit test. The teacher indicated that these packages present a framework within which students may begin to make connections, a process we call learning. However, the packages also provide the teacher with a measure of control — first, over the knowledge that is to be assessed, and therefore valued (for, as one teacher remarked, "Even if some of the topics are incredibly dry, they can be made more interesting with something the kids don't have to know"); and second, over his accountability to students and parents, school administration and school board.

A consequence of this packaging, given the institutional context, is that nonassessable or nonexaminable aspects of the official curriculum, such as attitudes, values, interpretations and critical thinking, tend to be neglected. These are the aspects that cannot be standardized because they are dependent upon ways of knowing that are idiosyncratic and ill-defined. The interpretive stance of the student is denied when it is required that he or she appropriate the teacher's or expert's knowledge framework in order to succeed, in terms of scoring marks. The following transcript illustrates the point; the teacher is providing a summary for the overall pattern of photosynthetic reactions, with the aid of a handout sheet on which the reactions are printed:

Teacher: These hydrogens are used in the next series of reactions with carbon dioxide, and the product is something which we'll write as CH_2O, and though the actual product of photosynthesis is not this (it's something else), it has these elements in that ratio. And what else is produced? Anything else? Well, there is water as a by-product. Here's the carbohydrate, and the carbohydrate that is actually synthesized by the plant is PGAL. What is the full name? You've seen this one before in respiration.

Student: Phosphoglyceraldehyde.

Teacher: That's right. So the actual product of photosynthesis is not sugar, not glucose, it's phosphoglyceraldehyde. And the plant will take those PGAL molecules and combine them into one molecule of regular sugar. . . .

Following the return of the marked answer sheets for the unit test (multiple-choice questions) on photosynthesis, one student was obviously puzzled by the fact that apparently he had misinterpreted the identity of the photosynthetic sequence.

Student: Can I ask a question about number 24?

Teacher: Yes.

Student: Why are sugars the end product in photosynthesis?

Teacher: Sugars? Well, PGAL is a product; the only thing is that the other things listed with it are not products. So the best answer has to be sugars, because all of the answer applies.

Student: Well, there shouldn't be any answer right.

Teacher: No. ATP, oxygen is a product, water is a product, and so are sugars.

Student: Well, I thought that after you go to the PGAL stage, that that had nothing to do with. . . [photosynthesis].

Teacher: Well, yes, the PGAL combines in a series of reactions to form sugars.

Student: But the sugars have nothing to do with photosynthesis.

Teacher: Well, no, they're the end product of photosynthesis, even though the actual molecule generated is phosphoglyceraldehyde. The plant will then take the phosphoglyceraldehyde molecules, and change them into sugar molecules, so obviously sugar is a product of photosynthesis. It's not direct; it's not the actual product produced by the photosynthetic reaction. It's only a step away from PGAL to sugars. If you look at any book, you'll see that the end product is given as sugars, not PGAL. It's just a matter of interpretation; you're going one step further. . . .

This student was unusually persistent in his attempt to put across his interpretation of the information with which he had been provided. On the whole, students adopted the line of least resistance, except when marks were at stake.

There were notable exceptions to the view of curriculum as factual knowledge. Open acknowledgement that a student's view of the world may differ considerably from that of an expert occurred occasionally. In these classes, the teacher had taken considerable time and effort to characterize knowledge as provisional and personal, and not as certain and expert-derived. Statements such as, "We talked in class about not accepting as 'fact' what the experts tell you," resulted in a nonthreatening atmosphere in which students could reveal their ideas without fear of ridicule. Similarly, student conceptions about natural phenomena are uncovered by their written answers to questions such as, "What do you think causes gravity?" In subsequent class discussions, this teacher has some knowledge of the students' frameworks.

More generally, students preferred to reveal interest in a specific topic by questioning the teacher during a private or small-group discussion, rather than in the full class. The following exchange occurred towards the end of a grade 12 class. The teacher had given a lecture on the theory of blood transfusion, and, following an open question period in which more factual information was provided, the teacher advised the students to use the remaining class time for reading from the text. One student stopped the teacher as he passed by:

Student: Why do we have the [blood type] antibody?

Teacher: I can't think of any natural use for the body being able to fight foreign blood protein. It's part of the genetic make-up of the individual.

Student: You can't, in nature, transfuse blood.

Teacher: No. But then, there's no use in your having different skin protein, different muscle protein than me. In nature, there's no need for my heart to be placed in your body. And yet that difference exists.

Student: It's just a coincidence.

Teacher: Well yes, although I'm not sure I agree with the term. It's more of a characteristic of the uniqueness of the individual. Everyone is unique because of your genetic make-up. It's one of the characteristics of nature.

Student: This thing may have some use, but we don't know what it is.

Teacher: Yes, I'm just shooting in the dark; it's just a theory.

The distinction between school knowledge and everyday knowledge persists in many instances. One teacher rationalized the existence of the gulf in this manner:

> "Maybe they'll never use the content, but it's the actual procedure they're going through in learning the stuff that is maybe important. Maybe that will help them to learn something else which is important. And then, of course, how do you know it's not going to be important?"

This separation of school and everyday knowledge seems to be closely associated with the taken-for-granted necessity of preparing students for either the next course in the high school sequence, or for the university courses. A chemistry teacher put it this way:

> "You've got to do the core, because the next course is based on the core. The options are interesting, but not necessary as far as moving on to the next unit. [The options] are just extensions, generally practical, everyday industry-type extensions on the core material."

It takes a lot of time, practice and drill in the physical science classes to bring student performance on the core concepts to a satisfactory level. Consequently, very few of the optional topics are included in the Chemistry 10 and 20 courses, or the Physics 10 and 20. In the grade 12 courses, one elective unit on radiation chemistry is presented in Chemistry 30, and one on the speed of light in Physics 30. Concern for the continuing progress of their students in postsecondary institutions directs the physics teachers in supplementing the prescribed physics core material. When viewed as a preuniversity or pretechnical college program, the current high school physics program has some "gaping holes which must be filled. We know what [the students] need to do at university and technical institutes."

The fact that Science 11 is viewed as a "terminal" course removes the necessity to provide a solid grounding in technical information for future courses; without the imposition of a detailed provincial guide, teachers feel free to mould the course around the interests of the students. One teacher expressed the opinion that Science 11 classes should offer something that students "will want to know later in life." At present, this criterion is interpreted to mean topics in human physiology.

The Science 11 course has the potential to provide an interpretive approach to scientific activity, but "unfortunately has acquired a certain stigma," remarked a school administrator, "and tends to be reserved for low achievers." In voicing the need for less theoretical, less mathematical courses, physical science teachers were quick to specify that such courses would have to be acceptable to the university, which is seen to be the gatekeeper of legitimate knowledge. At every level in the school system, the university community is viewed as authenticating school knowledge.

A notable exception to the separation of school and everyday knowledge has been the implementation in Biology 30 classes of a six-week course in the techniques of cardio-pulmonary resuscitation (CPR). All the biology teachers are qualified instructors for the course, and give up their lunch hours and spare periods to assist each other with instruction and testing. Teachers and students were highly enthusiastic about this project, valuing it as something that would always be useful to know, outside school.

An attempt to bridge the gap between school and everyday knowledge is made in a school-developed course, Ecology 20. This course offers students an opportunity to study the features and implications of local ecosystems. For the teachers of this class, a significant challenge arises in planning activities for the polarized groups of high achievers (the specialists) and low achievers (looking for easy credits) who make up the class.

Science and School Science

I have described a prevailing conception of school knowledge as being given, sequenced, standard and measurable; it is also distinct from common sense, everyday knowledge. These features describe, for the most part, the nature of knowledge to be acquired in school science programs. The "facts" are the products of much investigation, "a compounding of information gathered over the years." There is so much information that the teacher sees his task as that of "boiling down the information to the most important parts of it."

I heard very little discussion of science as an activity; critical consideration of the methods employed by scientists past and present played no part in the development of most topics. Research on cell membrane structure was portrayed to a grade 10 class in the following manner:

> "One of the labs at the university has been working on this for years, and they may never know the answer. The little bit that they uncover, they publish. Someone else happens to pick it up and do a bit more, and they add to the knowledge; and then someone else will come along and put it all together, and you come up with another model."

The big breakthrough is represented as being the consequence of years and years of "slogging" by large numbers of different groups of investigators.

Another aspect of research activities coming to be recognized by some science teachers in their classrooms is the politics of scientific investigation. I was told by one teacher that he mentions the interrelatedness of research grants, industrial applications, big business and politics. For him, the activities of scientists are not neutral and value free, and it is becoming increasingly important to discuss these ideas in class so that students may think about them and formulate their own informed opinions.

The provincial curriculum guide for biology specifies that historical aspects of the Biology 30 topics should be given "general coverage only," and teachers adhere to this guideline. They observe that it is difficult to generate enthusiasm for another era, given the advanced state of present-day information. All Biology 10 students should associate the names of two European scientists with the cell theory, advises the guide, but says nothing about why students should do so. Is it to consider the nature of theory and its relationship to the progress of science? One teacher put it this way:

> "Now it seems kind of simplistic today to come to the conclusion that living things are made out of cells. You've known that since you were in grade 1 or 2, when your first science teacher scraped something off a plant and put it under a microscope for you to look. But back in the 1800s, these two individuals, Schleiden and Schwann, came to the conclusion that each of the things [plants and animals] they were dealing with was made of cells. This particular statement, that living things were composed of cells, was a big breakthrough in the development of the cell theory."

A little later in the lesson, mention was made of the debate between church and science over the origin of life, but because the theories about the origin of life had been "covered" in the last unit, the issue was not discussed again.

Characteristically, the science classes studiously avoided rigorous discussion of the conflicts in which scientists have engaged. The current physics curriculum guide directs specific attention to the historical development of physical theories and to the manner in which the activities of physicists may be seen as reflecting the values and aspirations of the society in which they lived or live. But while this approach is felt to be commendable for a history course about physics, the teachers feel it is sadly lacking in the practical components of a physics course. The prescribed texts are considered to be adequate as long as the teacher has a good working knowledge of the concepts of physics and their practical applications. (Supplementary class texts are also used; see Appendix B.) One teacher explained how he adds practical applications as he teaches:

"Magnetic fields cause electrons to swerve, and I talk about how it does this in the picture tube of a television set, because I know how it works. But the television tube isn't mentioned in the book at all. All they mention in the book is that J.J. Thomson developed this cathode ray tube and he was able to bend electrons. But it doesn't strike home unless you can show them an example, and I can show them that."

The classical dispute about the nature of light was presented to grade 12 students in the following way:

Teacher: Generally, as we go through the readers, we keep name-dropping. And can you guess which one, in terms of the development of the theory of light, we start off with?

Student: Isaac Newton.

Teacher: And Huygens. We're talking about 1680, and the intellectual argument between the two groups. Newton's idea was that the behaviour of light is basically similar to that of particles, and so we have the corpuscular theory of light. Huygens, on the other hand, suggested that light behaves in a manner similar to waves.

The teacher then correlated the behaviour of particles and waves with the characteristics of transmission, reflection and refraction:

Teacher: The other argument is diffraction: waves tend to diffract. What was diffraction last week, Max?

Student: Particles diffracting off a mirror.

Teacher: Diffraction. You've got to know these terms.

Student: When it goes around a corner.

Teacher: Right. Bending around a corner. You can't see light bending around a corner in 1680, so you have a problem. This takes us roughly to the 1800s when a guy by the name of Young set up an experiment with the diffraction gratings, narrow slits and so on and was able to observe diffraction. This experiment is on page 253 in your text. . . .

Students are thus presented with a depersonalized development of the theory of light. In contrast, students in another class may be requested to stand in the shoes of an early scientist, and consider what it was like to be working at the time of Galileo. Students are asked to make their own value judgements in written responses to questions such as, "Do you think Galileo was treated fairly?" and "Do you think the same sort of thing could happen to a scientist today?" The teacher reflects: "It's difficult to mark, but I just want them to think about it." Using the historical development of physical concepts as a vehicle for the discussion of social, political and moral aspects of activities labelled as science is frequently frustrating for this teacher, who finds that the grade 10 and 11 students are not accustomed to class discussion; nor are they prepared to do routine practice for homework in order to accommodate class discussions. Grade 12 students do seem to avail themselves of the opportunity, but even then, "they don't seem to know anything that is going on around them."

The theoretical tools of scientists are given generally minor attention in school science classes. In two grade 10 classes, the following descriptions of two common scientific tools were given:

> "Models are not meant to be the final explanation; a model is an attempt that explains something. If you can build a model that explains different things that are happening, your model will be acceptable until such time as somebody else comes along and changes it slightly. Models are meant to try to explain things that are happening. They are meant to be changed; they are not the answer. I gave you a reference to a short paragraph in your text about the importance of models; this gives you a good idea of the importance of models in the development of theories."

* * *

Teacher: All the calculations are based on a theory that we're using all the time. What theory is all of chemistry based on?
Student: Mass.
Teacher: Not conservation of mass.
Student: Atoms.
Teacher: Theory of atoms. Now why is it called the atomic *theory*? *Theory*?
Student: [inaudible]
Student: [inaudible]
Teacher: How do you prove it? Nobody has seen these atoms. We don't know for absolutely positive that these atoms exist. There's no real proof, and yet we use the atomic theory. Why is the atomic theory so widely used?
Student: Because it works.
Teacher: Because evidence supports the theory. But I think Tom's answer is the simplest, that it works.

Laboratory Activities

There were more than 32 students in many of the classes observed. Teachers pointed to the logistical problems associated with arranging more than 30 inexperienced students around lab benches. "They've only got 40 minutes to get in there and gather data. So they have to be prepared before they go in, and know what they're supposed to do." Most teachers prepare for laboratory work during the preceding class, handing out detailed instructions and demonstrating the use of equipment. In all the sciences, laboratory classes involved illustration or confirmation of concepts theoretically derived in prior classes.

Teacher demonstrations seemed to be a popular alternative to class experiments; they tend to be less frustrating for the teacher and are certainly time-efficient. Grade 10 and 11 chemistry students are afforded little opportunity to develop manipulative laboratory skills. The course content leaves little time for lab classes, maybe one per unit. For example, the Grade 10 chemistry course is in its last few days, and there is insufficient time for the class members to individually confirm the law of conservation of mass by a quantitative investigation of a copper/silver nitrate reaction. The demonstration begun in one class by a substitute teacher is completed in a subsequent class by the regular teacher, who begins by writing the equation for the chemical reaction on the board and continues by writing down the calculations for the grams-to-moles-to-grams conversion. Turning to the class, he makes this comment:

> "Now that's how much we should get. See, this is what's called the 'theoretical yield'; based on the amount of silver nitrate we used, we should get this much silver: 1.94 grams. Now, let's see how much it weighs. I'll weigh the filter paper plus the silver."

The teacher weighs the filter paper and its collected silver on a beam balance on the front bench. Students provide the weight of the filter paper before filtration, and the necessary subtraction is made to give the weight of silver.

> "So you actually got 1.97 grams, but we should have got 1.94 grams. Well, that's almost right on. There could be various experimental errors. Let's calculate the percentage error. What's the difference between those two values? 0.03 is the difference. Now, let's assume that the theoretical one is the correct one; that gives us only one or two per cent. I think in this kind of lab, if you're within 10 per cent, it's good."

The nature of the possible errors associated with the weighings was not discussed further, even though the error was substantially larger for the copper.

Grade 10 physics students actively participate in a teacher-directed determination of acceleration due to gravity, in which particular attention is paid to the potential errors in the investigation.

Teacher: Now, what other things do we have to worry about with these stopwatches?

Student: When I dropped it [steel ball], you could hear "click, click, click. . . ."

Students: Yes.

Teacher: How are we going to deal with it? There certainly is going to be a problem with people's reaction time. Maybe we'll need a bit of practice with the stopwatches. And maybe we'll have to count a little bit before. I'd like you to think about it: how could we account for reaction time, and determine a way of determining what the reaction times are, for the timers?

What I find most often is, he's given you a clue as to when to start, right? He says, "Ready, 3, 2, 1, go." Well, there's a little bit of a reaction time there, but with people watching the ball, they see it fall, and they anticipate when it's going to hit. And they get in sync with that, and they set the watch off exactly when it hits. Is that good or bad?

Student: Good.

Student: Bad.

Student: Bad.

Teacher: Why is it bad?

Students: [no reply]

Teacher: Well, if it took them time to start the watch at the top, we should also make sure that they take time to stop the watch at the bottom as well. Then they might counteract each other. So I'm wondering if watching the ball on the way down is a good idea.

Student: Listen for it.

Teacher: He could say "Go," and everyone would take their time to start, and then when you hear the fall, you would take the same amount of time for it to stop. Because you're listening for his word to start, but you're watching for the ball to stop. That's not using the same reaction times. So we'll probably be wise to try to use the same sense. . . .

Later, the teacher added this point:

Teacher: Now, one thing. I'm wondering about the drop. He's counting and he's dropping. Would that increase or decrease the error, do you think? Because if he counts and he drops, he can perhaps anticipate it. So what would you suggest?

Student: Someone else counts.

Teacher: All right, Mark counts. Times all reset. Don't look at it.

And later still, the teacher commented on the results.

Teacher: So we have two determinations here. In one case, we had reasonably good precision; some of these values are pretty close. In the other case, we tried to get rid of some of the errors due to reaction time and whatnot. We're not exactly sure which is better; here we think we got rid of some of the errors due to reaction time, but these results are a little more precise than these.

This teacher studiously avoids the "right answer" syndrome, implicitly recognizing that knowledge is created by individuals doing certain activities. This understanding is reflected in comments such as "We can call this the experimental value, and that one the book value, because you can go to a book and look it up, because some other scientist has done it again and again and again and done it very precisely." A further point is made in the following exchange:

Teacher: Do you think that's a reasonable percentage error for an experiment?
Student: Yes.
Student: No.
Teacher: Now, based on this experiment, would you strongly believe that the acceleration due to gravity is around 9.8 metres per second squared?
Student: Yes.
Teacher: You would? Based on one experiment?
Student: Not really.
Teacher: That's why we're going to do another experiment tomorrow. . . .

Access to laboratory space and materials is not a difficulty in this school. Four teachers meet all their classes in laboratory classrooms, and the other teachers work in classrooms adjacent to laboratories. Two technicians work in a spacious prep room to supply all needed resources. And yet I gained the impression (which was confirmed by one teacher) that true experimentation or investigation does not take place within this institutional context. A biology teacher told me that when pressed for time, the laboratory exercises are sacrificed. He explained: "Lab work often is supplementary to what you've already taught. It can create a lot of interest, questions and curiosity. But the pressure to cover the material is killing that." The Biology 10 course provides students with the opportunity to study the characteristics and organization of cells in a variety of organisms. Apart from making wet mount preparations of onion epidermis or cheek cells, examination of representative cells and organisms is limited to commercially prepared slides and preserved specimens. Students are rarely expected to complete formal laboratory reports or scientific drawings. Dissections of earthworms, frogs and foetal pigs are completed in one or two class periods per dissection, with the objective that students be able to recognize the organ systems previously described to them.

The Biology 20 course is viewed by teachers as consisting of two major sections: ecology and genetics. A component of the ecology section is a field trip to a poplar forest beyond the city limits, during which students are introduced "to some of the procedures conducted by a field biologist in the study of a natural ecosystem." Such procedures include vegetation analysis using a quadrat or transect, analysis of invertebrate distribution, soil analysis and the recording of physical conditions. Students work in groups of three or four, gathering data for assigned procedures. In subsequent classes, the analyzed data are compiled and tabulated for the whole class, and students are required to write a report or answer a series of questions related to the interpretation of the data. This ecological investigation is intended to illustrate to students the orderly and methodical features of scientific inquiry, and students are expected to discuss possible sources of error and the limitations of any generalizations drawn, and to identify new problems that come to light. One teacher described the project as unrewarding for both himself and the students. His experience has been that students have only "a superficial understanding of the scientific process (hypothesizing, testing, inferring), and even though the junior high school science program emphasizes these process skills, when it comes to being analytical and able to evaluate data, even the brightest students have difficulty doing that." However, this is likely to be the first extended biological investigation conducted by these students.

Messages about Science: Chemistry

In the classes that I observed (portions of which have already been described), the emphasis was on students' acquisition of a set of principles accepted by a majority of the educational community as being the foundation for further study. The first priority in these classes is to provide a recipe for arriving at the correct answer to any question that might occur on a test. It is felt that students require a great deal of practice in applying the rules derived from any particular concept, and considerable class time is devoted to the working of examples by students. Students must learn the conventions in terminology, as is indicated in the following dialogue:

Teacher: Let's have a look at number 14. It's a common one, ammonia.

Student: I don't understand why it wasn't nitrogen trihydride.

Teacher: O.K. We never say dihydrogen oxide, do we? We always say it's water. It's the same with this one. If we use the correct molecular terminology, it's nitrogen trihydride, but we don't use the correct one because these are common chemicals and we just have to memorize their names. We know this is water, and we know this is ammonia. That's all. What are some of the other common names you must know?

Student: Methane.

Teacher: Good.

Student: Ozone.

Student: Ethanol, methanol.

Teacher: Now, don't confuse this ammonia with this one [writing on the board] $NH4^+$. What's $NH4^+$?

Student: Ammonium.

Teacher: That is your ammonium complex ion. Now ammonia you can have as a pure compound, a jar of ammonia. But you can't have a jar of ammonium ion, because ammonium has to go with something.

Overwhelming concern for the drill of these core concepts has resulted in the elimination of elective units, which present opportunities for understanding everyday phenomena in terms of chemical principles.

Messages about Science: Physics

Students in grade 10 classes are exposed to a number of intertwining themes about science: science not just as a body of knowledge but as a series of human events, each with a particular social context and social implications; scientific knowledge as provisional and personal.

The grade 10 year seems to be sufficiently distanced from university entrance requirements to afford flexibility in approach, but the grade 12 year falls under the shadow of grade expectations, and recipes for correct explanations are almost inevitable. As already mentioned, teachers supplement the grade 12 core material in anticipation that students will have need of this information at university.

Messages about Science: Biology

The prevailing message about biological studies is that there is a vast amount of basic information that students should acquire, even if they are not going on to become professional biologists. Teachers talked about "information overload," but they were reluctant to select any areas that, given the option, they would delete from the high school program. The Biology 30 course entails a study of human physiology; because the systems are interrelated, none can be omitted, although the teacher "may choose to give a superficial treatment of the biochemical aspects of some [topics], such as muscle contraction."

Considerable chemical terminology is retained in topics such as cell respiration and photosynthesis, although students have little experience of the practical significance of the terms.

Struggling against the surge towards correct answers, satisfactory grades and future course requirements is a wave of interest on the part of students and teachers in understanding and possibly controlling everyday phenomena. On several occasions, the need to talk about topics that are interesting and useful, but not detailed in the curriculum guide, was expressed. The implementation of the grade 12 CPR project illustrates one way in which this interest is demonstrated. Another illustration is provided by the topics for the grade 12 term paper; students select one of the following biological problems for a structured, written account: cancer, molecular genetics, nutrition or environmental control.

Social Interactions

The secondary school timetable requires a teacher to face a large number of groups of students for short periods of time. This arrangement tends to stress group rather than individual relationships, the latter being somewhat fragmented and almost impersonal. For teachers who acknowledge that knowing and learning is an individual process and who see themselves as facilitators of that process, the large classes are a perpetual frustration. They must devote their attention and energies to the motivation and control of groups, not individual learners. Commented one teacher: "It's a very fine balance that has to be maintained between keeping them involved and motivated, and total chaos. I have to go with them, bend with the wind." And another teacher: "You have to be able to play the students like instruments." The implicit assumption of teachers and students alike is that it is indeed the teacher's responsibility to motivate and control the discourse in each class; for the most part, students passively conform to the directions and expectations of teachers. Such expectations include regular and prompt attendance, and cooperative responses to teacher-posed questions. The doors of most science classrooms remain open during the instructional periods, and the occasional latecomer is overlooked. However, I observed one grade 12 group that had succeeded in generating considerable antagonism between itself and the teacher by not observing these expectations. Persistent late arrivals were confronted by locked doors on several occasions, to be climaxed by the total cancellation of class on a day when seven students sauntered in minutes after the class had got under way. The teacher offered these comments on the reciprocal nature of teacher-student responses: "You recognize that with an unresponsive class, your own reaction reinforces the somewhat negative attitudes among students. If the kids are not interested, you use the same old material, which is dull and turns the kids off, which makes you fall back further. It's a vicious circle."

I observed that many teachers relied upon "trading for grades" to motivate student cooperation and response. The dates of unit tests were prominently displayed in every classroom and, in some classes, there were frequent references to the "next" test. Some teachers appeared to go out of their way to assist students in coping with tests:

> "The first thing to do is go through and answer all the questions you can do easily. Then go back and do the ones you know you can do, but have to calculate. Get those done. Then go back and do the ones you're having difficulty with. And at the last resort, guess. Make sure you get all the marks you can."

Another teacher offered this advice:

> "I suggest very strongly that you write your final physiology exam around the beginning of May. It seems only logical to write the final [immediately] after you've finished doing the unit, instead of having a month in there without doing any physiology, and then having to come back and review it. I'm proposing we'll build a review week into the end of April, and then you write the final."

I have already mentioned that the organization of their day essentially isolates teachers from their colleagues. Several teachers spoke of this; one teacher had begun his teaching career by team teaching, an experience he valued for the exchange of ideas and opportunity for reflection on the art of teaching that it provided. He has now become acclimatized to the fact that there is only "me and my classroom," with the occasional student teacher or researcher observing, a situation that has persisted throughout the 11 years of another teacher's career. This lack of shared experiences leads to stagnation. It also contributes to a "live and let live" attitude, in which teachers find themselves accountable primarily to themselves. Depending on the individual, this may contribute to, or protect him or her from, concern about effectiveness. Another aspect of isolation was the concern expressed for keeping in touch with the scientific community, its current developments and issues. After eight years of teaching, another teacher remarked that he felt he was beginning to lose touch: "You can keep up-to-date by reading appropriate articles, but that is not the same as being in the field."

Following an extended discussion of the many alternatives available in teaching science, one teacher told me that he had never before considered such possibilities; his daily routine does not normally allow for such reflection. But another teacher countered the suggestion of seminar sessions for science staff, pointing out that they would place still more demands on the teachers. And indeed, attempts to stage a group discussion of science education objectives during this study were unsuccessful.

Yet despite the daily routine, the teachers have an implicit understanding of what can be expected of them by the school administration, students and parents. Over the years, course materials have been adapted, so that in each section of a course students are exposed to a similar breadth and depth of information. Standardizing the course content in this way satisfies the administration's concern for uniformity, but it also provides the teachers with a collective strength for influencing classroom activities and implementing changes. One administrator noted:

> "I'm much happier being the facilitator of change if it comes from a group of teachers. Individuals, I'd be pretty cautious about — that it isn't just some kind of bandwagon he's on for a few months. But if the whole department thought it through, and the department head is acting as the immediate leader, and if I agree with it, I suppose I'd have to be fairly enthusiastic, too."

The teachers in this science department have recognized that, although the educational institution resists individual modifications and innovations, collectively they may exert influence. Thus they have successfully modified provincial prescriptions for investigative student projects in terms of what is practically feasible and what will appeal to the students. Commitment to the CPR unit as a biology project is one result of this collective action.

Tensions in Teaching

My conversations with the teachers disclosed underlying tensions between the responsibilities and the rewards of teaching. These science teachers indicated that they view their primary responsibility to be that of effectively preparing students to succeed in their continuing education. They achieve this end by ordering the prescribed content of each course into a logical, testable sequence of objectives, by providing the resources and opportunities for learning and by evaluating students' achievement with respect to the objectives specified at the beginning of each unit. In addition, teachers consider themselves responsible for maintaining an accurate record of students' attendance and achievements, for preparing lessons to ensure that instruction proceeds smoothly and for keeping informed about current scientific topics and issues.

Unanimously, these teachers linked the rewards of teaching with the establishment of positive interactions with students. Rewards were not dependent upon student understanding or achievement in school science but upon student response, particularly enthusiasm or cooperation. One teacher put it this way: "I would much rather win a kid over to being [in school] than to learning all the ins-and-outs." And another teacher: "It's the quality of the interaction that is important. The secret is to know the course content very well, so that you can devote your energy towards interacting with the kids on a personal level. You might as well use video if all you're interested in is course content."

One teacher said he found difficulty in experiencing the "feeling" that he felt he had to generate in each class of the day. This teacher felt a personal responsibility to "appear enthusiastic, pleasant, in control (but not worried about it), and enjoying himself, even at the end of the day." For this teacher, every class is an encounter that holds the potential for establishing a rewarding relationship with students as individuals. It is not enough to lecture about science or to provide instruction in the techniques of science. There is a compulsion to reach out to students, and in so doing, to give meaning to the act of teaching.

The institutional context imposes the necessity for grading students' performance in order that students may be directed into appropriate channels of training and further education. This requirement involves the efficient processing of hundreds of students, all needing a series of grades for credits. Teachers are confronted with a demand for marks that is incompatible with a personal interpretation of science and its activities. Some teachers take it for granted that the high school curricula are bodies of information to be transmitted; others feel constrained to comply with this view. Assessment procedures are incompatible with a view of science as a human interpretive activity, yet they satisfy the demand for credentials.

Teachers are faced with a series of contradictions and conflicts. They seek personal interactions with students, yet are confronted daily by large groups. Some teachers rely on this group social interaction for their motivation and reward, while others find it perplexing and frustrating. The task of providing an education in science is overridden by the goals of supportive group membership, enthusiastic cooperation and teamwork. The occupational isolation of teachers prevents the sharing of teaching experiences and reflection on their meaning. In the effort to fulfil their perceived responsibilities, teachers have no time to pause. Their many responsibilities, perceived and actual, effectively remove teachers from active scientific inquiry, yet they are expected to keep abreast of new developments. For many science teachers, the experience of teaching involves a daily search for a reasonable balance between responsibilities and rewards.

Appendix A

The following course descriptions are found in the 1981-82 program guide for students:

Science 11 (3 credits)

For students who want to meet basic requirements for a high school diploma, Science 11 is a general science course that covers introductory units in biology, chemistry and physics. The course reflects the needs and interests of students.

Biology 10 (3 credits)

Biology 10 is an introductory biology course adapted from the BSCS program. Units of discussion include the microscope, the cell, classification systems and an overview of plant and animal life. Wherever possible, laboratory work is included.

Biology 20 (3 credits)

Biology 20 introduces and pursues in some depth four of the topics that constitute the biological sciences. The topics – cell division, genetics, evolution and ecology – are supplemented with discussions of developing research and appropriate laboratory work.

Biology 30 (5 credits)

The emphasis of the course is on biochemistry, molecular biology and physiology. Students will study units in energy conversions, human physiology, current biological problems and process development. Biology 30 is designed for students with a strong interest in biology or who will be entering a postsecondary school for which Biology 30 is a prerequisite.

Chemistry 10 (3 credits)

Chemistry is the study of compounds and the interaction of these compounds. Chemistry 10 deals with the structure of the atom, chemical formulae, balancing chemical equations, the mole concept and the mathematics of chemistry. Laboratory work accompanies the study of each of these topics. Mathematics basic to chemistry will be taught.

Chemistry 20 (3 credits)

Chemistry 20 examines the following topics: Chemistry 10 review, solution chemistry, the mathematics of solution chemistry, chemical bonding and organic chemistry. Laboratory work accompanies each of these topics.

Chemistry 30 (5 credits)

This course consists of a short review of Chemistry 20, followed by a study of chemical energy, oxidation-reduction reactions and acid-base reactions. The material studied is closely integrated with laboratory investigations. Optional units of interest are studied at the conclusion of the core material.

Physics 10 (3 credits)

Physics is the scientific study of the relationship among matter, energy, space and time. The topics are kinematics (motion of objects) and dynamics (the causes of motion of objects). Algebraic and graphical description, analysis of forces, and motion are prevalent in this course.

Physics 20 (3 credits)

The major emphasis in Physics 20 is the study of the laws of conservation of momentum and energy and the nature and propagation of waves.

Physics 30 (5 credits)

Physics 30 includes topics on light, magnetism, electricity and some atomic physics. An additional unit on mechanics deals with the interrelationships of force, mass and energy.

Ecology 20 (3 credits - Special Project Credit)
The course is restricted to Grade 11 or 12 students who have a keen interest in nature study and conservation. It provides an opportunity for students to study in some detail the structure and function of ecosystems, and the effects man has on them. World ecology will be included but Alberta ecology will be emphasized. There will be an opportunity to conduct field studies, enabling students to develop biological sampling techniques, followed by laboratory study and analysis of the sample.

Students will be expected to be able to work effectively, both on individual projects and in groups. Students who are considering Ecology 20 should discuss this possibility with their science teacher, the science department head, or a grade coordinator.

Appendix B

The following texts are purchased by students:

Biology 10:	James H. Otto and Albert Towle, *Modern Biology*, Holt, Rinehart and Winston of Canada, Ltd., Toronto, 1977.
Biology 20:	Biological Sciences Curriculum Study, *Biological Science: An Ecological Approach*, BSCS Green Version, Third Edition, Gage and Co. (Rand McNally), Agincourt, 1973. (To be phased out in January 1982 and replaced by Otto and Towle.)
Biology 30:	John W. Kimball, *Biology*, Third Edition, Addison-Wesley, Don Mills, 1974.
Biology – IBP:	W.A. Andrews *et al.*, *Biological Science: An Introductory Study*, Prentice-Hall, Scarborough, 1980.
Chemistry 10:	F. Jenkins *et al.*, *ALCHEM 10*, J.M. LeBel Enterprises, Edmonton, 1979.
Chemistry 20:	F. Jenkins *et al.*, *ALCHEM 20*, J.M. LeBel, 1979.
Chemistry 30:	F. Jenkins *et al.*, *ALCHEM 30*, J.M. LeBel, 1979.
Physics 10:	Douglas Paul, Denny Peirce and Kenneth Stief, *Physics, A Human Endeavour, Unit 1, Motion*, Holt, Rinehart and Winston of Canada, Ltd., Toronto, 1976.
Physics 20:	Douglas Paul, Denny Peirce and Kenneth Stief, *Physics, A Human Endeavour, Unit 3, Energy and Conservation Laws*, Holt, Rinehart and Winston of Canada, Ltd., Toronto, 1976.

Physics 30:	F. James Rutherford *et al.*, *Project Physics, Unit 4, Light and Electromagnetism*, Holt, Rinehart and Winston, Inc., New York, 1975. F. James Rutherford *et al.*, *Project Physics, Unit 5, Models of the Atom*, Holt, Rinehart and Winston, Inc., New York, 1975.

The following texts are retained as class sets for reference use in school by students:

Biology 30:	Richard W. Wagner, *Environment and Man*, Second Edition, George J. McLeod, Ltd., Toronto, 1974.
Biology – IBP:	W.A. Andrews *et al.*, *Biological Science: An Introductory Study*, Prentice-Hall, Scarborough, 1980. William T. Keeton, *Biological Science*, Third Edition, W.W. Norton and Company, New York, 1979. Karon Arms and Pamela S. Camp, *Biology*, Holt, Rinehart and Winston, Inc., New York, 1979. Helena Curtis, *Biology*, Third Edition, Worth Publishers, New York, 1979.
Chemistry – IBP:	Ernest R. Toon and George L. Ellis, *Foundations of Chemistry*, Holt, Rinehart and Winston of Canada, Ltd., Toronto, 1978. Ernest R. Toon and George L. Ellis, *Foundations of Chemistry, Laboratory Experiments*, Holt, Rinehart and Winston of Canada, Ltd., Toronto, 1977.
Physics 30:	James T. Murphy and Robert C. Smoot, *Physics: Principles and Problems*, Charles E. Merrill Publishing Company, Columbus, Ohio, 1977. Robert Stollberg, Faith Fitch Hill and Marvin H. Nygaard, *Fundamentals of Physics*, Canadian Edition, Thomas Nelson and Sons (Canada) Limited, Don Mills, 1968.

VII. Science Teaching at Red Cliff High School

Lawson Drake

The School

Red Cliff High is a rural high school offering grades 10, 11 and 12. There are some 750 students, the majority of whom come from rural backgrounds. They are the children of farmers, fishermen and tradesmen. A small percentage have parents who are in the professions.

The school operates on a full-credit semester system, which means that students take three or four full credits during the first half of the year and three or four different full credits during the second half of the year. Most courses are offered in both semesters. The school day is divided into four 80-minute periods, beginning at 9:00 a.m. and ending at 3:30 p.m., with a one-hour break at noon. The teaching days are arranged on a six-day cycle. In the science subjects observed in this study, each class has one period per day per subject. Minimal graduation requirements stipulated by the Department of Education are 15 credits, of which four must be at the grade 12 level and not more than six at the grade 10 level. However, the school administration encourages all students to earn at least 18 credits over the three years and requires that at least one science course be taken in each year.

The classes observed were grade 10 science, grade 11 physics and grade 12 biology. A minimum of three periods of observation were made in each class. From tape recordings and written notes, a record of classroom observations was made and given to the teacher to be checked for accuracy. After receiving the teacher's agreement that the record of classroom observations was accurate and fair, one or more discussions were held with each teacher. Transcriptions of the classes and discussions were correlated with the record of observations. A second account of the classroom observations, expanded to include relevant excerpts from the discussions, was submitted to each teacher to be verified for accuracy and fairness.

Grade 10 Science: Learning by Discovery

This class of 27 students meets in their teacher's homeroom, an inside classroom with no windows. A periodic table of the elements hangs on one wall. There are no services and no demonstration table. The class is using *Introductory Physical Science* (*IPS*), an "academic" science course, in which, according to the school handbook, students perform a variety of laboratory experiments, and from these experiments draw conclusions that advance their program in the study of matter. Grade 9 academic science and a good mathematics background are listed as prerequisites for the course.

Mr. Bond, the teacher, was asked about the importance of *IPS* in the life of students at his school.

Bond: I would hope that students particularly interested in science would take it, and that's true in most cases. We have three science courses and *IPS* is supposed to be for those with the most aptitude for science. We can't stream the students, because they come to us from other schools; I think that the final choice is left to the student, but I understand that they receive some direction from their junior high school. We get some students with very little ability in math and it's very hard for them. I don't know just how much counselling they get.

Drake: What about their background in general science, coming up from the lower schools?

Bond: I wish they didn't have any! It creates problems for me. Students have the idea that science is a story, like history, that they can read. It's not a way of thinking for them.

Drake: In terms of a story, do they come with their facts straight? Do they know the story?

Bond: They know far too much. They know all about atoms, molecules, compounds, elements; whereas we have to start with simple things like measuring mass and volume, and the nature of measurement, which they have never considered before.

Different classroom activities characterized each of three periods I observed. At the beginning of the first, the teacher called the class to order and took attendance. Students interrupted to ask, "Do we go to lab today?" There seemed to be an eagerness to attend lab.

During the preceding period, the class had done an experiment on fractional distillation. The teacher asked the students to refer to their lab notes and results from the experiment and to their reports on which they had been working at home. He set up a table on the blackboard, listing properties of the three fractions obtained and asked the students to provide the data. Students who had not already done so were told to include this table in their reports. The teacher then questioned the class on entries to the table: "What is the evidence that fraction two is a mixture? That fraction one is pure and fraction three is pure?"

Students referred to the "intermediate" nature of some properties of fraction two. They had some difficulty in establishing the identity and/or purity of fractions one and three, however. Alcohol and water were the suspected substances, but densities and boiling points were not in agreement. The teacher said that the density determination might not be accurate and asked why. A student replied, "Because of the small sample size," and the teacher referred to the effect of error of measurement on small and large amounts.

The student's response, and the teacher's comments on it, serve to illustrate what this teacher saw as one of the principal challenges in teaching this course:

Bond: What I find most frustrating is teaching the students measurement and getting them to accept that a measurement is uncertain. It takes a couple of months before many will accept that. When they come in, numbers are exact and certain; it takes a lot of experience, a lot of class work, before they realize that a measurement is uncertain, that you have to think about these measurements before you can come to a conclusion.

Drake: What happens in their minds if they make two measurements and they don't agree?

Bond: When they first go into the lab they'll try to make them agree. A lot has to do with reading the instrument, and the book emphasizes estimation when making a measurement. For example, on a ruler, the smallest division has ten equal parts, and one can estimate between these. This is a completely new idea to them, but if you can get them to do that then I think that they start to believe in the uncertainty of measurement. If they just read to the nearest division which is there, then I don't think they will believe.

The teacher continued to discuss the results of the lab work. Having decided that fraction one was the alcohol, the teacher asked what kind of alcohol it was.

Students: Peroxide. Hydrogen peroxide. Methanol. Isopropanol. The density is fairly close, boiling point is close.

Student: Butanol?

Bond: Why not tertiary butanol?

Student: The melting point is way off.

Bond: Yes, it would have been a solid at room temperature.

Student: What two things are in fraction two?
Student: Very first boiling point curve should show two liquids, right?
Bond: Yes, and all subsequent data confirm this.

This kind of interchange led us to consider the way in which *IPS* is supposed to be taught.

Drake: The philosophy of this course is learning by discovery, right?

Bond: That's right. Something which should be said about the whole course is that the investigation approach, or the inquiry method, where the student finds things out for himself, is a lot of baloney. It should be obvious to anyone who thinks about it that the course is very structured and you're deciding what questions the students are going to ask and you're deciding exactly how they are supposed to find the answer.

Drake: Do you think that students require too much leading and too much direction?

Bond: There is certainly a temptation for a teacher to lead them too much and give them too many directions. We all like to get right answers.

Drake: Is it at all a question of impatience at the speed of the thing? Do you want to be getting on with other things while they are floundering around trying to find an answer on their own?

Bond: Well, I try not to push them too fast. This year I didn't even try to complete the course. We'd lost a few days through storms and I did not make the effort.

The teacher now assigned questions 17 and 18 from the end of chapter 5 and told the students, "You have five minutes." The remainder of the class period was spent analyzing a recent class test. Each question was dealt with in detail, and students were advised to take notes on "what you got wrong, because you will be having another test on this material." Points mentioned by the teacher included rounding off of numbers, recognition of significant digits, correct use of units, setting up ratios and plotting graphs. Following the analysis, the remainder of the period was spent making grade adjustments.

It was interesting to note that the analysis of test questions showed that students were having problems with the mathematics rather than with the scientific concepts involved. In an earlier discussion, on the content of junior high school science, the question had been raised as to whether a more rigorous approach could be taken in those grades, and this same teacher's reply was that it definitely could be. "They've got the math skills at grade 6 or 7; the math is very simple," he had said. But in view of the mathematical abilities displayed by the students in his class, the accuracy of his assessment is doubtful.

In the second lesson I observed, the class was given a reading assignment from the text. While the students read, the teacher moved through the room; no questions were asked of him. When the reading was completed, a question-and-answer session ensued. To initiate discussion, the teacher put the heading: "Petroleum (Crude Oil)" on the blackboard.

Bond: Petroleum is formed from what, Nathan?

Nathan: Dead plants and animals.

Bond: How did they become petroleum, Ann?

Ann: They died.

Students: Compressed.

Bond: Yes, by pressure of layers of rock above them.

Student: This is another way?

Bond: No, this statement tells how it happened. How do we extract it from the earth? The book explains how crude oil is found in porous rock. It is not a pool, but a sponge-like formation as in the diagram on page 72. Nonporous layers above and below keep the oil in place. How do we get it out, Nancy?

Nancy: A well.

Bond: It is not quite like a water well. How is it different?

Students: It gives oil. The bit is different. It's much deeper.

Bond: How do we lift it out of the well?

Student: Pumped.

Bond: Not all wells require a pump. How else may we get it? What is another source of pressure?

Student: Capillaries.

Bond: No. Nathan?

Nathan: Gas pressure.

Bond: Yes, gas pressure pushes oil to the surface.

Student: They use steam to loosen it up, too.

Bond: Yes, that's in older wells and sometimes they pump water down into the well to float the oil up. Then you learned about refining, which is an interesting form of fractional distillation. Page 7 [in the book] lists the different substances in petroleum, with their boiling points and densities. Don't need to know them all, but there are three main products. What are they, Darlene?

Darlene: Methane?

Bond: No.

Student: Fuel gas, gasoline and kerosene.

Bond: Yes, let's list these by properties. Tracey, what is the boiling point of methane?

Tracey: Minus 161.

Bond: So that will boil at 20°C, won't it? Even the butane will boil. Now, the middle fraction is gasoline, which also has numerous substances, all of which boil above 20°C. Why is this important?

Student: They would explode at room temperature.

Bond: No, they would evaporate, not explode. The third fraction is kerosene, the substance with the highest boiling point. Now another product is left behind when these are separated.

Student: Asphalt.

Bond: Yes, when you get to an oil refinery, whereas you used a test tube in fractional distillation, they use huge stills hundreds of feet high. What is asphalt used for?

Student: Paving roads.

Bond: Yes, mixed with sand and gravel.

This concluded the introduction to petroleum. The remainder of the period was to be spent in the laboratory.

Bond: Today we do a new experiment on separation. See page 74, "Separating a Solid from a Liquid." Put this definition in your notes: "Filtration: a method for separating insoluble solids from a liquid." And that's the method we'll use today in experiment 5.4, page 74. [Writes on chalkboard: Purpose: To separate a mixture of soluble and insoluble solids.] Look on page 75, you'll see the device used. It's called a filter paper, which you fold a certain way and place in a funnel. Soluble solid passes right through the filter paper. A solution will be clear, meaning that the dissolved substance is made of very tiny pieces, small enough to pass through the holes in the filter paper. Anything that won't dissolve won't pass through the filter paper. I will give you a substance which you should examine to see whether it is a mixture. Then you dissolve the substance. How will you recover the soluble substance?

Student: By evaporation?

Bond: Yes. The procedure is explained in your book. Just follow directions. What could prevent all the soluble substance from dissolving?

Patricia: May have a low solubility.

Bond: How can you be sure to dissolve it all?

Patricia: Add more water?

Bond: In the procedure there will be one small change; rather than use a clamp to support your test tube, put the test tube in the rack. [The teacher diagrammed the setup on the blackboard and students copied the diagrams.]

Student: What should be in our observations?

Bond: Well, we want to know if we have separated the substances. How can we tell? What did we do earlier?

Student: We tested flammability and stuff like that.

Bond: Yes, we call these the characteristic properties. What are they?

Students: Flammability, odour, colour, density, boiling point, melting point and freezing point.

Bond: We don't have time, and we don't want to identify all these. How do we test for flammability?

Several ideas were offered, none of them very useful. The teacher advised them to place a small amount of the substance on the end of a spatula, hold it in the flame of an alcohol lamp for a short time and then remove it from the flame and look for evidence of burning. After receiving a homework assignment for the next day, the class moved out to the science lab. This room is well equipped, with seven tables (each seating four students), each fitted with sink, cold water, gas and electricity. The room also contains a teacher's table and two movable tables, under-table storage (for alcohol lamps, evaporating dishes and heating stands), wall storage (for stock equipment), side tables around the room, a fume hood, a safety shower, an eyewash, a projection screen and a blackboard.

Students located and organized their apparatus. The teacher demonstrated how to fold filter paper, how to fill the funnel with water and how to exclude air bubbles from the space between the filter and funnel wall. He cautioned the class that measurements are approximate only. The students proceeded with the exercises; the teacher circulated, observing the procedure and answering questions. Some students worried about the residue in the test tube after pouring the contents onto the filter. The teacher reassured them that they need not get it all out. Students discussed their observations with one another. Some groups had difficulty demonstrating flammability of substance number one. One group did not hold the wet material in the alcohol flame long enough to ignite it; another group used a butane lighter rather than the alcohol lamp and mistook the accumulation of carbon from the flame as a sign of burning. One alert student noted the change in the colour of the flame when substance number two was tested and asked if this constituted flammability. She concluded that it did not.

Supervision of the technique was not easy. There was much spattering from evaporation dishes; students seemed to quite enjoy this, saying to one another, "Look at the snow!" as the white crystals spattered about. Also, there were accidents. One student had her long hair singed in the flame of a burner, hot evaporation dishes were picked up (and dropped), and a funnel was broken. Several safety-conscious students wore protective goggles. The exercise was done and clean-up completed before the period ended. I asked Mr. Bond how *IPS* fitted in with the rest of the science program.

Drake: What do you think of *IPS* in relation to the kinds of courses taught in grades 11 and 12?

Bond: It's a very good introduction to chemistry and physics.

Drake: The discovery approach is not emphasized in grades 11 and 12 to the same extent, is it?

Bond: That's right. In grade 11 chemistry we're back to the story book, which students find easier.

Drake: Is there a let-down from grade 10 to grade 11?

Bond: For a very small number of students, perhaps. For most of them it is more familiar — lecture, memorization, etc.

Drake: Is there a carry-over in lab skills?

Bond: Yes, definitely.

Drake: What about the content? You say it is a nice blend of chemistry and physics; could you see integration of life sciences in this course?

Bond: None at all. I think students have to have a basic understanding of measurement and experimentation before they can do anything and I think they already have quite a bit of experience in biology. Maybe there's a place for biology at the grade 10 level in another course.

The third and final session I observed began with the return of a test and its analysis. Mr. Bond next took up the homework assignment involving applications of their work on the separation of substances. A discussion with the students established their understanding of the problems and their solutions, and was summed up by Mr. Bond in these words: "So there are practical uses for the method of separation performed last day."

Bond: Today I'll do a demonstration. Here's a definition: "Chromatography: a method of separating coloured substances." Now, what is the purpose of experiment 5.7?

Students: To find out what black ink is made of. To separate coloured substances. [Teacher puts up a roll of chromatography paper.]

Bond: The book does not explain how this experiment actually works, but I know how to do it. This is special paper.

Student: Why?

Bond: It's absorbent. Make a point on the end of the paper and put the substance about one inch up from the pointed end. [The teacher applied the ink, but then found that this cylinder was too narrow for the paper strip; he found a wider jar.] O.K., now I lower the tip into the water. And the water is now rising on the paper.

Student: Capillary action!

Bond: You can do this for yourselves at home. Take home a strip of chromatography paper. There are all kinds of things you can test at home. Here are some things you can try. Food colouring.

Students: You mean, use that instead of ink? What about tinfoil?

Bond: I don't think it's necessary. Your book tells you it prevents evaporation of water.

Students: Can you use a jam jar? How long do you leave it?

Bond: Until you get separation. [The teacher notices that in the demonstration the paper had touched the side of the jar.] We have a problem here. [He readjusts the paper strip.]

Teacher and students then completed a list of coloured substances likely to be available in homes. The list included mustard, ketchup, iodine, mercurochrome, mascara, flower petals and leaves. Mr. Bond finished the lesson by giving the homework assignment, which was greeted by expressions of dismay. Students asked whether they should keep their notes, and Mr. Bond replied that because they would need to calculate densities, their notes would be useful. The students worked singly or in groups on this assignment. If they had questions, they came forward to the teacher's desk. Meanwhile, they were watching the progress of the chromatography demonstration. One student asked, "Will the material move right up to the top of the paper and off?" The query wasn't really answered. As the chromatogram proceeded, the students could see four colours in the black ink. No one asked why this should be or commented on the particular colours. There was some talk among the students about how colours combine to produce black. The matter was not pursued.

In going over the lesson we discussed its purpose:

Drake: You asked the students what the purpose of the experiment was. One said, "To find out what black ink is made of." Another said, "To separate coloured substances." The first student took a very specific view of what the experiment was about, but another student took the more general view that you were going to demonstrate a method for the separation of coloured substances, which to me is what chromatography is all about, and so I ask, do you find it common, in a course like this, for some students to go for the very specific, when, in fact, you may be trying to promote the general?

Bond: No, I haven't noticed that. I think I would say that when you begin an experiment most students feel that it has a very limited purpose. I think I would say that the majority of the class would think that it was to find out what black ink is made of. Perhaps when you have finished the experiment or done another similar experiment then they may be led to some general statement. That's certainly true in the first part of the textbook when they do experiments on the conservation of mass. I'm sure that when they are doing these they regard them as very specific questions but after they've done a number of them it is easy for them to see that there is a general conclusion they can come to.

Drake: So it would be fair to say, then, that students' perceptions do change as the course goes on.

Bond: Hopefully.

Drake: Yes, hopefully! And hopefully in this direction, from the specific to the general, which is the direction you want, I take it.

Bond: Yes, that would be a fair statement. That particular experiment doesn't add all that much to the course; it's interesting, students have fun doing it at home, but it doesn't really add that much in terms of general principles.

Drake: Would it be any more striking or any more interesting if it were done with plant pigments?

Bond: Every year I explain to students, according to directions in the textbook, how you should be able to separate pigments from plant leaves but none of the students has tried it yet. But neither have I.

Commentary

Three periods of observation of grade 10 science allowed me to see a number of teaching methods, as the following list indicates:

- Directed reading from the textbook, in the classroom
- Classroom discussion of the reading assignments
- Analysis of tests, with emphasis on teaching objectives as well as course content
- Preparation of students for laboratory experience
- The laboratory experience itself
- Postlaboratory follow-up: preparation of the report, discussion of data, comparison of results, etc.
- Classroom demonstration
- Discussion of assigned homework
- Solving problems in class

The physical environment of the classroom was stark, with little visual reference to the physical sciences except the periodic table of the elements. The laboratory, however, had the appearance and the appurtenances of an area where "science was done."

Mr. Bond said that he wanted to bring his students to an understanding of science not as a story but as a way of thinking, to emphasize calculations and the importance of measurement. He did not feel that the "discovery" method was really discovery, but rather a carefully programmed exposure to ideas, and he recognized certain danger areas:

> "Most of the things that the students are 'discovering' are the products of many fine minds and much hard work in the past. We devoted maybe one hour to 'discovering' the law of constant proportions, something which took many scientists many years to work out."

The discovery method can make science look too easy, but then, in his opinion, so can the "story-book" approach. He found that students came up from the junior high school, knowing "all about atoms, molecules, compounds and elements, whereas we have to start with simple things like measuring mass and volume, and the nature of measurement, which they have never considered before."

Are students turned off when they realize that there is a lot of careful work that has to be done to arrive at the information that is fed to them in a single sentence? Mr. Bond said, "Yes, in the past they've had colourful texts with diagrams of the nucleus, electrons, etc. It looks like it can all be learned in one page, whereas in five months in this course they never get to the nucleus." He is critical of the science taught in the earlier grades. "I don't think it's science at all. We give them a story, a history, but not science."

He said he would be the first to acknowledge, however, that the program has limitations. "There are no courses that are suitable for all students; streaming is required. Personally, I feel that we are wasting our time teaching students science, or telling many students stories, but obviously I am a minority in that view." But what of the contention that a knowledge of science is necessary for people to function as citizens?

> "People who say this don't really mean it. They don't really mean a knowledge of science, because if you want a knowledge of real science you have to take a course like *IPS*, in my opinion. What these people are referring to are story books in the lower grades, in junior high school. They even have 'science' in elementary school! And in university I'm sure that there are lots of story-book courses."

Grade 11 Physics: The University Stream

The school handbook describes this course as an academic course worth one credit towards graduation. It is not a required course, but many students in the "university stream" elect this course. The handbook describes the course as follows:

> "Physics deals generally with the study of matter and energy and their interrelationships. More specifically the. . . course covers the topics of measurement, motion, work, energy, heat and the kinetic theory of gases. The course includes a laboratory program which is a major part of the course, consisting of labs which are designed to reinforce course theory. [The course] is designed as a course for university preparatory and/or technical students, the only prerequisite is a good background in math problem-solving logic."

Two classes were observed. One class with 23 students (with roughly equal numbers of boys and girls) was described by the teacher as the "high achievers"; the other, with 25 students (about 75 per cent boys) was not considered by the teacher to be of the same academic calibre as the high achievers. Both classes covered the same work during the time I was in the school. The most noticeable difference in the teaching of these classes was that the teacher led the second class through many of the problems, whereas the first class was left much more on its own in working out solutions.

The physics laboratory is a small room furnished with eight tables, each designed to accommodate four students. There is a demonstration table at the front of the room and electricity is supplied to all tables. The teacher pointed out that the nominal capacity of 32 students caused overcrowding and that usually not more than 25 students used the room at any one time.

When I began my visits, both classes were studying the mathematical analysis of linear motion, a topic that had been introduced two days previously. The first five pages of chapter 5 in the text had been assigned for reading, with two or three questions from the text to be answered. In the period immediately preceding the observation period, this material had been discussed and the six formulae variously relating distance, time, initial, average and final velocities, and acceleration had been explained.

When the class of high achievers had been called to order, the teacher announced that the formulae given out the day before would be reviewed, but that first a question sheet would be distributed. Students were advised to try to answer the questions from their memory of yesterday's work, and to go to their notes only when they were unable to recall an answer. Students were allowed 15 minutes to work on this; during this time the teacher circulated, overseeing and giving aid when asked. Students asked about choice and application of the correct formula and about how the units combine. At the end of the working period the teacher called on individual students for their answers to questions on the handout.

The first and second questions of the handout concerned linear motion. The teacher said she wished to establish in students' minds the ideas that motion in a straight line might be uniform or accelerated. The fact that motion is relative to some other frame of reference did not appear to be stressed, while the constancy of uniform motion was stressed. The third question concerned symbols used in writing the formulae. Students were required to write the meaning of, and to give the units of measurement for, each symbol.

The differences between velocity and speed were noted but not stressed, and acceleration was accepted as marking a change in speed, either positive or negative. This seemed to be an accurate reflection of the textbook emphasis on these matters. Several students inquired about the relationship between negative acceleration and deceleration. The teacher said she was confident that the students had a grasp of these ideas and that the stated objective of the day's lesson was for students "to gain control of these formulas, to memorize them (if that's not a dirty word) in the hope that a little bit further along, they can apply them in different situations."

When I raised the question, "Will mastery of the formulas lead to a better understanding of linear motion, or should an understanding of linear motion lead them to develop the formulas?" the teacher's response was, "Well, when the formulas were introduced, I said, 'Here's one set for uniform motion; here's another set which will cover accelerated motion.' They are being set up for something which is coming." Upon further questioning, the teacher said that this day's lesson was not developed in response to a perceived need of this particular class; it was, instead, one of a standard sequence of lessons that experience has shown to be useful and effective in teaching this material.

When asked to rate student interest in this part of the course, the teacher, Mrs. Able, replied:

> "It's difficult even to rate their interest in physics generally. This class really goes for marks; whether the interest is in the topic or in the marks, I don't know. They are keen, but it's hard to judge the motivation. A lot of it may just be a means to an end."

When asked to give a personal rating of the importance of linear motion as a topic in the physics course, the teacher replied that the treatment of the topic was very mathematical; the students got a lot of it again in their mathematics through graphing, and so on.

Able: We are using a lot of tools, like the sine, for example, without going into the mathematical whys and wherefores, and when students complain to me about a lot of new things in physics, I try to explain this to them.

Drake: Does this provide an opportunity to show correlations between two disciplines such as math and physics?

Able: Yes, and having taught math for 10 years, perhaps I tend to overdo it. Students' problems are mainly with the math. Math skills need to be reviewed constantly, if students are to see appropriate applications. For example, to put metres over seconds and make a fraction just the same as by putting 2 over 3. Perhaps I'm putting my biases forward, but transposing a formula is a skill which they need if they are going to be adept at problem solving. The earlier they can get working with these things, the easier they'll find it.

Mrs. Able also pointed out that the Department of Education did not provide any specific guidelines for presenting the course in grade 11 physics. She relied for guidance on a course outline prepared by a colleague some years previously.

When the analysis of the handout sheets was completed, the students were assigned problems from the text. Mrs. Able led the class in solving the first few problems, questioning the students as to the formula required and the known and unknown elements in it. She then worked through the problem on the blackboard, emphasizing the importance of getting the units correct. "Your answer is not right," she told the class, "unless your units are right."

Having provided this model of solving problems, the teacher assigned further problems for work in class. The students were told, "Read the problem to find out what you're looking for and try to match that up with the appropriate formula." Mrs. Able moved through the room checking students' progress, offering help, answering questions and continuing to emphasize the choice of appropriate formulae and getting the units right. If a particular problem gave a number of students difficulty, she moved to the chalkboard to explain and work through the problem, while students copied the solution into their notes.

These events were the standard feature of the presentation of this topic. During my second observation, the class received a corrected test that covered vectors, force and motion. Correct solutions to the test questions were projected on the screen, and as the teacher analyzed each problem, the students corrected their errors. Later we discussed these events:

Drake: The sense of direction I get is that teaching physics is to provide a lot of problem solving, in the process of which, or in preparation for which, you provide a lot of examples. You work along with students, to show them the thought processes and the actual steps which have to be carried out to give them a sense of how to solve the problems and what the logic of the problem is.

Able: That seems fair.

Drake: So, why have you decided to do it in this way?

Able: That has evolved, I guess, as much as anything, from what I had to go by in terms of guides and outlines. That was how it was done previously, so. . . .

Drake: Would it also have been the way you were taught?

Able: Yes. The first year I had the course I sort of floundered around a lot looking for direction and guidelines, and one thing I did was to go back to my old college notes and I found that the way other teachers dealt with the course was very similar to what I did back then.

Drake: We are dealing with a topic of physics here — motion — which lends itself very well to this approach. Do you see physics mainly as a matter of problem solving, and do students acquire a view of physics as mainly solving problems? What appreciation do they have for theory and for descriptive aspects of physics?

Able: The earlier chapters in this text would give the impression that there is a lot of problem solving, but as they work into the grade 11 chapters, and for sure in grade 12, the theory becomes more prominent. The text becomes more theoretical, with fewer practical problems, as they get on into it.

Drake: Do you notice any change in students' attitudes toward physics as the emphasis shifts?

Able: Not to a great extent, I guess. It's an even split. Some really enjoy the problem work and don't take to the theory questions; written answers will be as brief as they can make them. Then there are others for whom the math aspect is not the first love; they see beyond that to get a kind of overall picture. I can't say one more than the other.

Later in this session the teacher introduced a new topic by assigning text material for classroom reading. While students scanned this material, the teacher wrote on the blackboard: "A body whose speed is increasing at a steady rate is considered to be undergoing positive acceleration. A body whose speed is decreasing at a steady rate is considered to be undergoing negative acceleration."

Students copied these statements while the teacher supplemented them by pointing out that another term for negative acceleration is deceleration. The teacher also raised the distinction between speed and velocity, pointing out that speed denotes distance travelled in unit time, whereas velocity is a vector, denoting speed and direction. Students also copied notes on positive acceleration and on the nature and value of "g." The students were then directed to problems on falling bodies and, as previously described, were led to choose formulae, identify variables and work towards a solution.

In our discussion of the lesson, I asked Mrs. Able whether the ready acceptance of values for acceleration due to gravity, and the like, was surprising:

Able: Unfortunately, no. It frightens me, sometimes, how docile they really are.

Drake: Can you judge where the students place the major emphasis; is it on the right answer or is it on the method of working towards the right answer? Do you think that they see the formulas which you give them as the key to reaching the right answer or as an embodiment of the reasoning inherent in the solutions of any particular problem?

Able: I would have to say that they see the formula as a tool to the right answer; it's the right answer which is the big thing.

Drake: In your teaching, how do you see yourself in relation to this question?

Able: Again, I'd say I'd like to think I am getting to the logic, to the reasoning behind it, but I'm probably not.

Drake: I am interested in whether certain classic classroom demonstrations are performed. For example, the movement of a coin and a feather through an evacuated tube?

Able: We don't do that one; we observe the fall of coins, as described on page 86 of the text.

Drake: In the text, the discussion of the motion of falling bodies is introduced with a description of Galileo's thought experiment. What, if anything, would students make of a thought experiment, and how would they relate that to his actual experiment of dropping various massive bodies?

Able: I'm not sure how to answer that. However, later in the course, when the contributions of Galileo and Newton have been recognized, students go to the library to prepare some biographical detail on those men. Whether that means much to them, I don't know. We don't really do the history the justice we could in many areas. The library has filmstrips which help the students in this area.

The third observation period involved laboratory work. In this course, laboratory exercises are done in conjunction with the class work, the exercises being chosen from those recommended in the text. Upwards of two class periods may be spent on a laboratory exercise; the experiment is first explained to the students, then performed in the lab and, after it is written up, the data are compared and the experiments are analyzed.

After the class was called to order in the classroom, the teacher directed the students to the lab manual. The teacher proceeded with an introduction to the experiment "Graphical Analysis of Motion."

"The problem you're attempting to answer is: How can the motion of a body be analyzed? In your answer you will have to summarize the procedure and the conclusion. You have the theory from Friday; 'Gathering the Data,' page 36, is where you will begin today. What is the period of vibration of the timer? Not the number of dots per second, but the time to make one dot, 0.01 to 0.03 seconds. Hopefully the timers have the period marked on them from when you used the timer last. Your name and the timer period should be on the box the timer was in. When you go to the lab, find your own timer and you won't have to determine the period all over again. Otherwise, you will have to go back and measure the period. How to do this is explained in the lab manual — move the tape through the timer for a measured three seconds, count the dots on the tape, divide the three seconds by the number of dots to find the time for one dot. Repeat three times and take an average value."

In this vein the teacher continued on through the rest of the exercise, emphasizing points of procedure and how to tabulate and interpret data, particularly with reference to preparing a speed-time graph. The teacher then reviewed the list of equipment needed, referred again to correct identification of the timer and advised students to gather their data as quickly as possible so as to have time to analyze the tape and prepare the graph.

The class adjourned to the laboratory where, following the teacher's earlier instruction, students acquired the necessary equipment to perform the exercise. The class was organized into teams of two students, with two teams to each laboratory table. Space for the most effective performance of the experiment was limited, but the teacher felt that using the smaller space was preferable to having teams wait in line to use the longer surface afforded by the demonstration table.

The strings by which the 200-gram masses were attached to the cart had been precut, and, as the equipment was assembled, I noted that the strings were too short, for when the carts were drawn back far enough to allow an adequate run of the cart along the table top, the 200-gram mass was 80 to 90 centimetres from the floor, instead of the recommended 30 centimetres. Thus, when the mass struck the floor during the actual experiment, the cart had neared the edge of the table and had little or no space left in which to decelerate.

Most teams were able to assemble the equipment with little difficulty. There were some minor problems with releasing the carts correctly and in having the carts "run true." No one complained about the length of the strings. No team felt it necessary to determine the period of the timer used, and all relied on the value accompanying their timer.

Heeding the teacher's earlier admonitions, the class quickly performed the experiment, put away the equipment and went to work on their data. The teacher circulated, observing progress, making suggestions and providing assistance when requested to do so. Questions related to calculation of "t" (number of dots x 10 x period of the timer), the method of determining "s" and the significance of having fewer values from their data than seemed to be required by the table in the text. Most speed-time graphs, when plotted, showed only accelerated motion, so that students were unable to select points of zero acceleration and negative acceleration. Later, I discussed the lab with Mrs. Able:

Drake: What do you see as the correct place of the laboratory in the course overall?

Able: The way that the text and the lab manual put it together I find works better than the *IPS* approach where they do the lab and then go to the text to build up the theory. I like this way of giving the theory in class, then repeating it in the lab manual and saying, "You are going to test this." Reference to the textbook is good reinforcement of theory, and I think reinforcement of the theory is better than the discovery method.

Drake: Having said that, do you feel that labs really teach or demonstrate procedures in the real world of science? Are they a relevant experience in that sense?

Able: In the real world of science? I would hope that they do. In chapter 3 we spend a good deal of time on dependent variables and independent variables, on what you measure and what you control and general experimental technique. I hope that they are getting an appreciation for accuracy and are learning techniques of use in the field of science.

Drake: What happens if the labs don't generate the data they are expected to? Does that ever happen?

Able: Oh yes. Earlier on, they just report what they find. But as the course goes on, and at the grade 12 level, since they are working toward an anticipated result, they should in their conclusion give per cent error and explain how close to the mark they came, and look for reasons [for discrepancies].

Drake: How would a student transfer this to the perceived situation of a scientist doing an experiment where he doesn't know the answer? Does this make students more or less sceptical of the results of real scientific work? Or do they relate their failure to get the "right answer" to vagaries of equipment or their own ineptitude?

Able: More the latter; I think that they probably feel that things are so absolute that if they are not getting the density of water to be one gram per cubic centimetre, then it must be their fault, they're doing something wrong.

Drake: And they don't think that a technologist, a scientist in the lab, would make the same errors?

Able: A lot of them really have no idea of how precise a technologist in a lab would be, and certainly the only shot at working toward an answer they don't know is in grade 10, and they have certainly matured a lot by grade 11. If they were working toward discovering something, they would be better geared for it.

Drake: In both grade 10 and 11 there is a good deal of "dry lab" preparation, and you attach a good deal of importance to this — that students should go into lab mentally prepared for what they are going to find, rather than have it sprung on them.

Able: Yes.

Drake: Do they like the labs? Girls more or less than boys?

Able: I find the girls at this age a lot neater, and the boys seem to be at an awkward stage. Girls have a little better skills, organization skills for sure. As for liking it or not liking it, there is no difference that I can see.

Observation of three periods of instruction in this course certainly bore out the significance of the statement in the school handbook that "the only prerequisite is a good background in math problem-solving logic." How adequate this background is for many of the students may be inferred from the emphasis the teacher placed on teaching simple mathematical skills.

Much of the teacher's previous experience was in teaching mathematics, and she more than once confessed to a possible "math bias." She provided this description of her objectives for the grade 11 physics curriculum:

Able: I'm pro sciences and I'd like them [the students] to get an exposure or a science background in high school if they can, because according to my way of thinking, it is important that they do get this background. That would be one objective. Another thing I would like to see done, and I know we're fairly short on it, is sort of seeing where physics fits into the overall picture and how they can use it later. I don't know what kind of a "PR" job is needed. Physics usually. . . each year I'll get one or two students who will come back and say, "I was scared; I always heard it was so hard and I'm glad I took it because I didn't find it that way." I don't know what we can do to dispel that idea because, with all the new technology and so forth, physics is becoming more and more necessary for students.

Drake: Is it a question, then, of really relating it to the world they live in?

Able: I think so, but I don't know how. I don't know where it has gotten this mystique, that you don't consider physics unless you're. . . .

Drake: Marked for university?

Able: Yes. It's too bad, really. I'm teaching grade 10 and registration is coming up for next year, and there will be all kinds of questions when they are told that they have to take a science in grade 11, and that the choices are chemistry, biology, physics, agriculture and home economics. They don't have any problem with home ec or agriculture, or probably with biology; the questions always are, "What's chemistry?" and "What's physics?" and to say that in chemistry you do this, this and this and in physics you do that, that and that. . . . I don't know how, other than getting into it, they will really find out what it's like.

Drake: Are there things you'd like to do, but don't do, and why?

Able: I'd sound complacent if I said "No," wouldn't I? One thing I'd like to think they are learning beyond physics is some skill at organizing their thoughts, whether in writing a lab report or whatever. A certain amount of self-discipline, which goes with any study but with science in particular, the regular keeping up with the work, that could stand them in good stead at any time.

Commentary

The presentation of this course is not just the reflection of this teacher's mathematics bias. She is teaching physics as she was taught physics, and as some of her colleagues teach physics. She follows the text closely because the text gives order and direction to activities of the class. She uses the textbook illustrations and demonstrations and chooses laboratory exercises from among those recommended by the text. There is not a lot of innovation from year to year. Her strategies are straightforward, and may be summarized as follows:

1. Introduce a small amount of theory, with some demonstrations, but with chalkboard and overhead projector as major classroom "tools."
2. Show the application of the theory through problems, and develop the problem-solving logic through emphasis on formulae and units.

3. Drill for learning, using textbook problems and additional problems and questions by handout, then reinforce the theory with a laboratory exercise and move on to the next small amount of theory.

Grade 12 Biology: Teaching by Objectives

Grade 12 biology is the academic course in biology. The student handbook offers this description:

> "The chief topic of the course is the Animal Kingdom. Invertebrate and vertebrate organisms are studied with emphasis on evolutionary relationships existing among the various phyla. The last section of the course deals with the development of man and various aspects of human biology as time permits."

The textbook, *Biological Science*, by Gregory and Goldman, is used for both grade 11 and grade 12 biology. Grade 12 biology is essentially zoology; cell biology and botany are covered in grade 11.

I met the class first in the biology laboratory, a room with desks (each seating four persons) arranged around the sides of the room, leaving a large open space in the centre. The room also contained a teacher's table, a preparation table with a sink, a growth chamber (climaterium) not in use and two aquaria. Compound microscopes were available from wall storage cabinets. Teaching aids included plant and animal charts, meiosis and mitosis models and a selection of microscope slides. Dissecting trays and kits of instruments were present in the storage space of each desk. A project room and a greenhouse were accessible from the laboratory.

During my first visit, the class was engaged in dissection of the frog, using preserved and injected leopard frogs. The teacher handed out the specimens, and students resumed dissecting at the point where they had stopped the day before. The system to be dissected first on this day was the digestive system. Students worked from a manual, with the textbook and a handout diagram of the bullfrog for assistance. A wall chart of the frog dissection was also available. The teacher circulated to give directions. Students seemed to prefer to use instruments more than their fingers. There was a good deal of comparison between dissecting teams. The manual's instructions related to pithed frogs, which the students had not seen, rather than to preserved material. The class did not observe live frogs. Some students made notes, but there were no lab drawings made. One group tried to study lung structure, using a dry lump of tissue on a slide. They had difficulty interpreting what they saw.

As dissection of the digestive system was completed, the teacher gave some general instructions on how to proceed with the circulatory system. He noted that the manual was deficient in detail and that both the textbook and the handout would be useful supplementary material. Above all, he emphasized that patience and painstaking care were called for in this phase of the work, as the vessels were traced from the *truncus arteriosis* outwards. The students took care to wash out the specimen and clean up their instruments at the end of the lab period.

The next meeting with this class took place in the biology classroom, which has no furnishings to distinguish it particularly as a place where biology is taught. The subject of the day's lesson was the vertebrate classes Reptilia and Aves. The class began with the teacher distributing an objective sheet. The teacher first went briefly through it, suggesting what might be required by some of the objectives and indicating which ones would be supplemented by films, and so on. He then proceeded to deal in detail with the objectives, beginning with the textbook page on which reptilian characteristics are presented in chart form. The teacher prepared a blackboard listing of these characteristics and elaborated on each:

Aspen: Right off the bat we can think of exceptions [to reptiles having two pairs of limbs]. What are they?

Student: Birds?

Student: Snakes.

Aspen: Yes, no legs on snakes; maybe tiny bulges sometimes. Recall from yesterday's film the modifications of sea turtles' limbs for swimming. [Teacher writes on the board, "Heart imperfectly divided into 4 chambers 2 auricles."] What is another word we use instead of auricles?

Student: Atrium.

Aspen: Yes, pluralized, Donald?

Donald: Atria.

Aspen: Yes, two atria and an imperfectly divided ventricle. I'll come back to this in a little while. For the crocodilians the division of the ventricle is complete, with important implications for the efficiency with which the organism functions.

He continues to write: "Respiration always by lungs." Students make no comment. Then he writes:

"Body temperature variable. Fertilization internal. Compare with amphibians as to extent to which they are adapted to life on land."

Aspen: What were some of the shortcomings that amphibians had to contend with, Chris? [No immediate response. Then, under prodding, these comments emerge:]

Students: Suitability of limbs for life on land was not great. Eggs had to have enough water. Reptiles lay eggs on land. Lung had to be assisted by skin respiration. Skin of amphibians had to keep moist.

In this manner the lesson continued. The students were led, by questioning, to an appreciation of the necessary adaptations to a life on land. Characteristics of groups studied earlier and references to the film seen the previous day were part of the interchange. When Mr. Aspen came to the third objective on the objective sheet, he set a deadline for the required essays on dinosaurs and bird migration. The 200 to 250 word essay on characteristics of birds that enable them to fly was to be done to the students' own satisfaction and retained for exam purposes, not handed in. The sources for the essay on dinosaurs were articles in *Scientific American* and *National Geographic*, and the teacher asked for information in three specific areas: (1) a system of classification suggesting relationships, (2) a comment on the pros and cons of warm-blooded dinosaurs and (3) some possible reasons for the extinction of dinosaurs. The teacher advised the students to expect to find numerous theories, none of which would be satisfactory to all critics.

The class worked through the objective sheet, making notes as required. In dealing with reptile classifications, Mr. Aspen spoke of how authorities could disagree over the number of living orders. He wrote the following on the board:

Rhynchocephala — tuatara
Chelonia — turtles, tortoises
Squamata — lizards and snakes
Crocodilia — crocodiles, alligators, gavial, caimans.

Student: What are these last ones?

Aspen: Smaller members of the crocodilians. There's an article here in the September 1978 *National Geographic*, "A Bad Time to be a Crocodile." I'll just refer to a couple of items here. Not bad pictures, Brian, of the various kinds. [Reading] "They are not very cuddly; they don't have big eyes like baby seals. What's happening worldwide is that many of these species are near extinction." [He reads further from the article, referring to the use of crocodile skin and the wanton hunting of these creatures, showing some of the illustrations. He notes the strong sense of territoriality and shows a picture of a frog being eaten.]

Student: But doesn't the frog have poison?

Aspen: Toxins of frogs vary from species to species and may do little more than spoil their taste.

Students: Aren't they eaten by birds?

Aspen: Perhaps just after hatching.

The pattern of classroom activity was unchanged during the third observation period, described by the teacher as a clean-up session. His plan was to deal with questions at the end of the text chapter on birds, to show an introductory film on mammals, then distribute an objective sheet and initiate a discussion on it. This is exactly what happened. In dealing with the text questions the teacher first ensured that he received a satisfactory answer, after which he encouraged some free discussion or took the opportunity to introduce some novel idea. In our discussion of these classroom events, the following points emerged:

Drake: What is the purpose of the objective sheet?

Aspen: It outlines what I want to achieve in a particular chapter. It gives students clues to my expectations of them in the various chapters. And it is a control on myself so that tests and evaluations will be related to what was done in the classroom. I do a reasonably good job of that. The first of these purposes [to provide an outline of the chapter] is the most important. I encourage that as a bare minimum and encourage the outside reading as enrichment or an application of science not presented in the text.

Drake: So, the objective sheet takes them back to the text?

Aspen: My objectives tend to be fairly close to the book, supplemented by outside reading, whether from *Time, Newsweek, Scientific American, National Geographic* or whatever. Those are things which in many cases don't relate to what is covered in the text and which will take the students beyond the text; they are pretty well limited to things I have read and found interesting. However, I am basically guided, in objective formation, by my own sense and experience as well as by the text emphases. There is no direct influence from the Department; they suggest chapters only.

Drake: In the classroom you prefer a free-wheeling atmosphere. Do you have any tricks for encouraging dicussion?

Aspen: One criticism over the years has been that I do not allow enough discussion.

Drake: Do the students feel inhibited, or what?

Aspen: No, it's a matter of them feeling that I talk too much. I don't have the facility to develop that interest which becomes contagious and leads to all-out discussion. That depends, of course, on the students and on the topic. If I'm teaching genetics, things are much livelier.

Drake: Do you have any special techniques for using films in your teaching?

Aspen: Well, of course, the big advantage of films is that they show living things in action in a way that textbooks can't do. I try to use them as a springboard from which a text chapter is developed.

Drake: Are there other strategies you wish to mention?

Aspen: I think that in terms of my effectiveness (or lack of same) in the classroom, my personality contributes more than any particular body of information or the value of my instructional methodology.

Commentary

While the text and its accompanying laboratory manual are at the core of the course, Mr. Aspen makes considerable use of outside reading materials, mostly magazines. The presentation of the course is descriptive rather than experimental, qualitative rather than quantitative. The use of an objective sheet by Mr. Aspen gives order and direction to the classroom presentation, but does not inhibit digressions as appropriate themes come up. Mr. Aspen is also vice principal and hockey coach, so that his relationship to the students is somewhat different from that of some other teachers. The excerpts from the observation record give a good picture of laboratory and classroom events during the observation period. Inasmuch as the presence of a researcher in a classroom is a powerful determinant in the presentation of any course, and in particular recognition of this teacher's closing statement, this commentary deals primarily with aspects of the teacher's philosophy and outlook that have not been specifically highlighted in the record of classroom events.

Drake: Let me ask you, what are your major objectives in teaching grade 12 biology?

Aspen: I start on the basis of a fairly divergent group in this class, students with varying commitments to biology as a subject area. So I try to provide two sets of objectives – one set for the minority who want a basic introduction to biology which will enable them to carry on in a biology program later, not only not at any disadvantage, but with a few ideas about biology which will lead to a commitment. Secondly, to meet what I see as the needs of the majority – those who will take no more biology – I try to provide an appreciation of the majesty, the extreme complexity and the order that exists in a living organism, with an attempt to provide students with a very logical and natural acceptance of the existence of a supreme being, in terms of things where they are today, that our planet is still being very much directed by some superior force.

Drake: Does that give you any trouble with evolutionary theory?

Aspen: It doesn't for me.

Drake: Does it for the students? Do you try to relate the two?

Aspen: I do, without intimidating, or making people who find a view of evolution rather distasteful, too uncomfortable. I believe very strongly in evolution, but in a God-directed one; I don't at all see why the three to six billions of years during which life is thought to have existed should not reflect God's way of increasing the complexity of the whole planet.

Drake: On this whole theme, do the students evince much interest in it?

Aspen: I don't know whether they come into my class feeling that way beforehand, but I think that the majority of them leave feeling that way.

Drake: So it's one of your objectives, at least to awaken this idea in their minds?

Aspen: Without intimidating those for whom it is going to be distasteful, and it's difficult at times to get that as a compromise. So, as to a very broad general objective, it would be that kids appreciate the complexity of life, to maybe relate that to our Christian heritage in terms of life in this province. A little more specifically, it would be to allow youngsters who will never take more biology to be a little more appreciative, a little more aware, of some of the issues they're going to have to deal with as voting citizens in our society.

Drake: How about biology as a science; do you try to make that part of your presentation?

Aspen: I think I do. I'm not sure I'm successful in providing kids with techniques of experimentation or of taking accurate data, and so on. I don't think I achieve that as thoroughly as I should.

Drake: Much biology is not quantitative in the sense that physics and chemistry are. Do you think that students therefore see biology as a soft science, and do they recognize its close relation to the physical sciences?

Aspen: I certainly try, at the start of my course each year, to indicate that if they are going into science after high school, they must have chemistry, physics and math. I don't impress that on them on a daily basis, though.

Something which I do try to stress is an understanding of our system of classification, the importance of Latin names when no one learns Latin any more. I spend a good deal of time on that – the need, the historical development, why it has ended up as it is, and so on.

And something else we have not seen during the observation but which I try to do a lot of is attempting to relate the study of biology to some of the moral, but not necessarily religious, aspects of biology. For example, pest control policies, implication of new technologies in medicine, the patenting of seed stock, and so on. I try to address matters like these in a general way, to get students to understand that these things are the stuff of biology and are important issues for the citizens of Canada in the late 20th century, and that they should have at least a minimum understanding of biology in order to cope with them and with the social and political issues. I don't know how well I do it, but I do address it and feel that it is an important part of the study of biology.

VIII. Lavoisier: Science Teaching at an École Polyvalente

Pierre-Léon Trempe

When I was asked to participate in this project, the prospect was an exciting one. At last, science teaching was to be looked at from the inside, from the perspective of the actors themselves as they live their daily lives. This, in contrast to the somewhat myopic vision of the outside observer who meticulously gathers facts to feed into a computer.

For a while, I hesitated, and for good reason. This was a risky business. It would be necessary to trade the security of preformed hypotheses, of refined instruments, of rigorous statistical analysis . . . for the insecurity of the unexpected.

Would I find something significant? Something other than trivia? Above all, something of help to science education?

I did, however, have two questions in mind: how is science taught, and why is it so taught?

So I met teachers and students in their own world — the classroom, the cafeteria, the halls ("agora"). I watched, questioned, listened. And progressively, I perceived a pervasive malaise — difficult to identify, until one day it all seemed to become clear. This malaise, it seemed to me, was clearly one of alienation. Was I right? You be the judge.

The Context of the Study

This research took the form of a case study — a fairly recent phenomenon, at least in education, particularly in Québec. Case studies, as conducted by anthropologists and others for many years, normally rely on formal and informal interviews, personal documents and, most important, the technique of participant observation. In this study we used all the above techniques, which complement each other. Using only one technique would not have produced the same quality of results.

Methodology

A study of this sort depends largely on correct procedure for its success. I therefore prepared a short paper setting out the purposes and methods of the study and sent it to the teachers involved. This document was the spearhead of the study, so to speak. It had to be drafted with great care, and because it was used to set the stage for the study, I reproduce a part of it here to indicate what I said to the teachers at the outset about my intentions:

> "I should make it quite clear that my purpose and that of the other researchers working on the study is not to produce a comparative study of the various situations, nor to *judge* them – still less to judge the various parties involved in them – but to *understand* as much as possible about the situations and what has made them as they are. You will probably reply, quite rightly, that it is very difficult to keep from judging. I agree this is so, and I am no better than the next man at resisting the tendency. I can assure you, however, that I will do everything possible to abstain from passing judgement, and use my resources primarily to understand as much, and as thoroughly, as possible.
>
> "By this point you will probably be wondering what exactly this research is aimed at. Two questions will provide the focus for this study. They are closely related: *What learning situations are actually offered to students in the sciences?* and *What factors have a decisive influence on these learning situations?*
>
> "Let me clarify by illustrating each of these two basic questions with subsidiary questions. In connection with the first: What set of objectives does the teacher actually pursue in class? What material does he or she actually use in his or her work? What teaching strategies does the teacher actually use to achieve his or her objectives? What does the teacher actually emphasize? and so on.
>
> "In connection with the second: What constraints (imposed by students, their parents, superiors, the Ministry, and so forth) must the teacher work with? What are the working conditions (rooms, timetables, regulations, availability of material and so forth)? What support does the teacher have (education consultant, monitor, col-

leagues, university teachers, specialized library, and so forth)? With what types of clientele does the teacher work? What room to manoeuvre does the teacher have, or in other words, precisely how independent is he or she? What does the teacher want to ask for? Does he or she perceive science teaching otherwise than as it is really practised? If so, how does he or she perceive it, and what prevents the teacher from implementing his or her perception? and so forth.

"How shall I go about gathering this information? I must make plain from the outset that a case study cannot be planned initially with the same precision as a traditional descriptive study, with its standard questionnaires, statistical analyses, and so forth. This is a *field* study, such as anthropologists carry out. Its exact procedure unfolds as the study progresses: hypotheses occur along the way, and appropriate research methods are chosen to suit them. Nothing is eliminated a priori, so that if an event of interest (as regards the study) occurs, attention is directed to it, and time is taken to examine it thoroughly. Unlike traditional studies, which deal only with general trends and whatever is generally applicable, the case study deals with singular events, so as to grasp the underlying truth. In this type of research, the important thing is not to find what is similar, but to try to understand what *is*."

I sent the document, from which the preceding extracts are drawn, with a covering letter to the director of the school board governing the target polyvalente. He discussed the matter with his staff, including the principal of the polyvalente, and agreed to my request. The director, his staff and the principal met with me briefly and we soon reached a complete agreement. They all showed great interest in the study. The principal undertook to call a meeting of his science staff some weeks later (in mid-June) so that I could make contact with them. I sent a personal letter to each of the eight science teachers, asking them for their cooperation. Enclosed with it was the document given to the administrators. A few days later, another letter was sent, asking the eight science teachers to attend the information meeting scheduled for the end of June. The meeting was held. Everyone came! After two hours' discussion, I wrote in my notebook (which I took everywhere after that), "I feel they have reservations, but they all agree in principle. So I shall make individual appointments with them for the end of September. We're off and running!"

At the end of September, I met with each teacher privately. Tape recorder in hand, I put my two questions to them: "How is science taught and why is it taught that way?" I listened, and asked more questions for clarification. They quickly became relaxed and communicative. They spoke spontaneously about everything: the way they taught, the material they used, the problems they encountered, the students, relations with management, program requirements, society and everything under the sun.

My recordings, nearly an hour each, were transcribed, giving a total of some 200 pages of typescript: a substantial body of information. A preliminary examination uncovered a few possible themes, but nothing clearly defined. Behind the teachers' anecdotes and personal opinions, I felt an uneasiness common to them all, but I could not identify it.

In late October, November and early December I was at the school again. This time, with the teachers' permission, I went into the classroom. I attended lectures, laboratory sessions and exercise periods. I observed, listened, questioned and, eventually, even helped teach a few students who were having trouble. I spoke with teachers, individually or in groups, between periods, at noon hour and after 3:30. Sometimes I made appointments; other times I came unexpectedly: sometimes in the morning, sometimes in the afternoon, sometimes for the whole day; at the beginning of the week, or near the end — rarely in the middle.

I went all through the school to soak up its atmosphere: the cafeteria, the assembly hall, the library, the cloakroom. I listened, watched and asked a few questions now and then. And I took notes. Everything went into my notebook. When I left in December, I had more than 120 pages of handwritten notes. Sometimes I wrote my notes wherever I happened to be; other times I withdrew for a moment and came back later. I never postponed taking notes, however, for fear of forgetting.

From late October to early December I must have spent roughly 80 hours at the school. As I grew to know the place, my vision grew sharper. I was increasingly aware of what interested me: the various signs of possible alienation among the participants. During the period January to March, I reviewed the literature on alienation and its chief symptoms, and designed the theoretical model described in the next section. During the period March to April, I examined all the information I had amassed in light of this model and completed a preliminary report.

In May, the preliminary report was distributed to the eight teachers concerned but to no one else. A few weeks later, the entire group met, away from the school. Everyone had a chance to air his or her views. A few changes were made to the text. The session was taped. This confrontation with the preliminary report was an integral part of the study. An addendum was prepared for the revised preliminary report, outlining the highlights of the latest meeting. The final report was now ready.

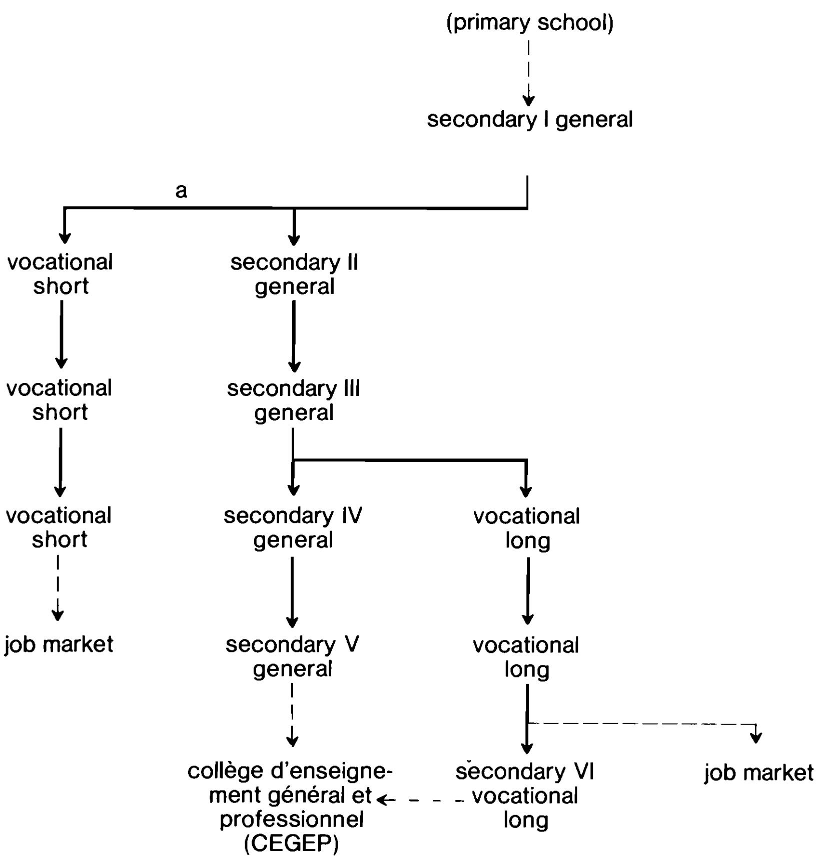
Setting and Actors

The polyvalente which was studied is a French-language institution near the centre of Québec. It has approximately 1500 students and 125 teachers. It is served by a system of school buses which carries a mixed urban, semiurban and rural population, drawn in part by the vocational training offered by the school. Nearly a third of the students come from economically disadvantaged backgrounds.

The administrators say that, on the whole, the school is fairly representative of polyvalentes in Québec: not too big or too small, not too avant-garde or too conservative, with the same types of problems as elsewhere. In short, it is no better or worse than anywhere else, as one teacher said. I share this view.

The school serves a varied clientele. It offers two streams, vocational and general, for students from secondary I (grade 7) to secondary V (grade 11), and also secondary VI for two trades and a short vocational program for assistants in certain trades. Figure VIII.1 shows the possible paths offered by the school.

Figure VIII.1 – Chart of Possible Paths



[a] If the student is 15 years old and a "battery of tests" shows the transfer is justified.

The science department comprises eight teachers. To preserve anonymity, I shall refrain from describing them in full. I shall only say that men are decidedly overrepresented and they are all approaching or past 40 and have taught for over 15 years. Of the eight teachers, two teach physics, two teach biology and two teach chemistry. The seventh teaches ecology, and the eighth, who has just been "parachuted" (as they say here) into science after teaching mathematics for 17 years, teaches an "introduction to physical sciences." All except the last have been teaching science for many years.

The physical appearance of the school deserves a few words. It is a large concrete structure set in a huge green field, surrounded by shopping centres and a fairly new subdivision.

Let us go in and take our first look at the building. The time is 11:48. I happen to have chosen the entrance leading into the hall. This is a very spacious room; at the centre, the ceiling is some 10 metres high. Opposite, huddled against a wall, is a little glassed-in booth for the supervisor of students. Everything is quiet. The sun streams in through windows near the ceiling. A few people are lounging on the benches that run all the way around the room.

A bell sounds. My watch says 11:50; I move on. . . 11:52. Suddenly there is a blast of music with a heavy beat (which a student later tells me is "progressive" music!). Then a flood of students surges from all directions. There is almost no jostling, but they move quickly. Many of their faces are striking: sad eyes, drawn faces, very few smiles. (I have a feeling of unreality.) The crowd seems to be moving in one direction. I follow it. We come to the cloakroom: low lights and a low ceiling, only three metres high. Straight lines of lockers, hundreds of lockers. Doors slam, locks bang against the metal walls, making a deafening din. People bump into one another, pulling on their raincoats and making for the doors, or grabbing a bag and heading in a different direction. I follow these people to the cafeteria, a large room with glaring fluorescent lights. At one end is a big bay window overlooking the bus parking lot. The tables and chairs are made of metal tubing and veneer. The noise is very loud but bearable. On the concrete blocks of the wall are two enormous, brightly coloured posters from the Department of Social Affairs depicting fish, fruit and vegetables. Opposite is the line-up for the lunch counter.

Leaving the cafeteria, I am again struck by the deafening music in the hall. I feel my muscles tense as if for a spring. I find a staircase and go up. Behind a closed door at the top is the gymnasium. It has a high ceiling, so it seems like a large cube of some 20 metres. Some students are playing ball. I retrace my steps and ask a student where the library is. "In the basement," he answers, "but it's closed this time of day."[!] I ask when it is open, and he replies, "During class and at recess." Fleeing the music, I take the first corridor I find. At intervals along the walls are brightly coloured murals with violent contrasts, no doubt painted by students at the school. Then classrooms. They all look much the same — well lit, with tables and chairs of metal tubing, green chalkboards. I continue walking, and find a washroom — locked! I shall have to wait for the next one. The linoleum floor of the corridor shows hundreds of cigarette burns. Another washroom, also locked! (Later I am told that they are always locked up!) I turn back towards the hall, guided by the music, and run up against a dead end. The doors from this corridor to the hall are locked with a chain and padlock. I turn back.

Finally I come to the hall. Hundreds of students are sitting around on the benches, leaning against the massive pillars, sitting side by side on the staircases or simply standing around. Many are unkempt: shirts hanging out, scruffy jeans and half-laced work boots. I make my way through the crowd with difficulty. Despite the din, some seem to be talking! Laughter breaks through here and there. Some people seem to be watching the passers-by casually. Then comes the principal, silent and inscrutable, on his tour of surveillance. A bell rings above the bedlam. Time to go back to class. The crowd begins to move, slowly, towards the corridors. The music is switched off suddenly. Silence returns to the walls shrouded in cigarette smoke. The supervisor shuts the metal grill leading to the cloakroom and bars it. I leave in a daze.

Teaching Practices

"Three 60-minute periods in the morning and two in the afternoon." What do these periods comprise in the sciences?

It varies. Apart from ecology, science teaching consists of four types of activity: occasional lectures, several laboratory periods, frequent exercise periods and regular examinations. Ecology has hardly any "labs" and comparatively few lectures; in essence, the only two activities are examinations and exercises on "work sheets" based on the textbooks. We should note in passing that physics, chemistry and biology are optional courses offered only in secondary IV and V. Introduction to Physical Sciences is another optional course at the secondary III level, while ecology is compulsory in secondary I. Classes comprise between 20 and 30 students as a rule, with roughly equal numbers of boys and girls in each.

Lectures

Lectures more or less parallel the textbook: *PSSC* for Physics 452/552 and 422/522; *CHEMStudy* for Chemistry 462/562; *Biologie humaine* (Désiré et al.), *Biologie* (Cournoyer and Garon) and *L'homme dans son milieu* (Couillard et al.) for Human Biology 412; *BSCS* and *Biologie moderne* (Otto and Towle) for General Biology 422; and *ISP* for the Introduction to Physical Sciences. Ecology is taught mainly from an exercise book entitled *L'écologie au secondaire* (Dubé) and two textbooks, *Les êtres et leur milieu* (Viscasillas) and *Perspectives écologiques, introduction à la biologie* (Thibeault et Daoust).

The students do not own these books, which are merely made available in the relevant science rooms (where most of the various teaching activities take place). With the teacher's consent, students may take the books home from time to time. I was told that this arrangement makes the books last longer and keeps the students more motivated, for few students want to work at home.

As a rule, lectures follow laboratory work. They summarize the information which the students are supposed to have gathered from the labs. The labs thus provide a "concrete" basis on which the teacher's presentation rests. The lecture also rounds out the material that needs to be covered and prepares the students for the exercises at the end of the chapter and the examination that follows. Some teachers also show films from time to time.

Students usually sit at lectures, pencil in hand, waiting to copy down in their notebooks whatever notes the teacher writes on the board. The rest of the time, unless they are exceptional students or something of special interest comes up, students doodle, chat with neighbours or simply stare vacantly into space. The teacher writes whatever he or she considers important on the board, often in full sentences; the criterion for determining importance is the probability of the point occurring in an examination set by the provincial department. To capture students' attention, teachers say such things as, "This is important, the Ministry asks for it three times out of two!"

There seems to be tacit connivance between teachers and students in this. It seems that the students know that, whatever they may do while the teacher is speaking, they cannot miss the information required for the examination if they are careful to copy the teacher's capsule notes on the board. Because the important thing is the examination, or rather the final mark, why should students listen to the presentation if the capsulated notes guarantee them success? All the more so because many students say "teacher talk" is boring. The teachers, for their part, reason that, because students do not know how to take notes, they must be told exactly what to write in their notebooks. "That way, at least they may remember something of what they copy. We could give them mimeographed notes, but they refuse to read. In fact, they can't read! So we have to write the notes on the board."

The teachers are aware that students do not pay attention during lectures, and have their own ways of trying to attract students' attention. They may slip in a joke (sometimes in questionable taste): "I know the girls won't understand," they smile (remember that all classes are mixed). They may use bizarre catchwords such as P-MAT (a mnemonic for the sequence prophase, metaphase, anaphase and telophase) or they may direct an unexpected question to a student who is obviously daydreaming. They may raise their voices, or drop the magic phrase "for the exam"; they may give examples from daily life, or use any of a number of tricks.

When I attended lectures (given by five or six different teachers), I sat at the back. I listened to what the teacher was saying, but my attention focussed rather on the noise, as well as the students' behaviour. I was amazed at the noise level prevailing while the lecture went on: the ventilation system, chairs moving, whispers, occasional bursts of laughter, echoes in some places, shuffling papers and so forth. (Not to mention the times when the intercom interrupted the lecture, as often happened when I first visited the school. At such times there was even more noise: no one seemed to want to hear the announcements.) The noise level where I sat was so high that sometimes I could hardly understand what the teacher was saying. Eventually the noise made me quite tired. It may be different for people who are used to it, or maybe they no longer notice. Perhaps, however, they are still affected by it.

I mentioned earlier that there are few formal lectures; in fact, they take up no more than a quarter of total class time. They are fairly short because of time wasted, especially at the beginning and end of the period. They seldom begin less than a good five minutes after the start of the period, for students trickle in slowly. Some talk with the teacher while others find a seat, take out their papers, settle down, chat with Tom, Dick and Harry and so forth. Then the teacher takes attendance and waits a moment for the class to calm down. Finally the lecture begins. Towards the end, five or even 10 minutes before the bell, the students may begin packing up their belongings and watching the clock. Thus, actual teaching takes up only about 40 of the 60 minutes. Indeed, a teacher told me, "I say to them, 'If you listen to me for 50 minutes, not 60 — maybe only 40, in fact, with all the little jokes I throw in — you won't have to waste time studying at home.' That gets them! I hear them saying to each other, 'What's he talking about?' I repeat it and explain what I've just told them. I tell them that their attention span is finite."

Laboratory Periods

Roughly equal proportions of laboratory and exercise periods make up the largest part of teaching time, with a good 30 per cent of available time devoted to each activity (except for ecology, where laboratory work consists of only three sessions with the microscope early in the year).

Labs always follow a very precise written procedure. Sometimes students are given handouts and sometimes they must copy down what the teacher writes on the board and discusses. Sometimes they must copy into their notebooks from a published laboratory workbook. The procedure may be quite explicit, depending on the situation. It may take the form of instructions for a set of operations or a series of questions.

Two examples follow. The first example deals with determining the freezing and melting points of naphthaline. After listing all the materials required, the teacher writes on the blackboard. The secondary III students copy into their notebooks, without seeming to pay much attention to what they are writing. As the teacher writes on the board, he pauses to let the students catch up and adds information orally:

Procedure:

1. Put the beaker stand on the board.
2. Fill the beaker three-quarters full of water and put it on the stand.
3. Set up two retort stands.
4. Insert the thermometers into the corks.
5. Lower a thermometer into the water and attach it to the stand by the cork.
6. Lower the test tube containing the naphthaline into the water and attach it to the stand.
7. Light the burner and place it under the beaker.
8. Heat until the naphthaline is completely melted. Insert the other thermometer in it and note the temperature.
9. Record the water temperature and remove the burner.
10. Results: [The teacher provides a table into which students must insert their results.]

Record the temperature at which the naphthaline solidifies. Chart results. Draw two curves: one for the water temperature and the other for the naphthaline temperature. [The teacher draws both these curves on the chart, in any case.]

In the second example, the teacher hands out two mimeographed sheets. The following is an extract from them. The secondary IV students have just used a disc on an air cushion, which gave them a series of points on a sheet of paper. The lab deals with the movement of a projectile:

1. What is the shape of the trajectory followed by the projectile?
2. How long was the projectile in flight?
3. Measure its range.
4. Measure object's horizontal speed at 0.10-second intervals and draw up a chart.
5. What is the average horizontal speed?
6. What type of horizontal movement impels it?
7. What is the variation in horizontal speed between:
   (a) 0.0 and 0.2 s
   (b) 0.0 and 0.5 s
   (c) 0.0 and 0.6 s

8. Calculate the acceleration in the above intervals.
9. Measure the horizontal distance travelled by the object between:
   (a) 0.0 and 0.2 s
   (b) 0.0 and 0.5 s
   (c) 0.0 and 0.6 s
10. Using the equations for this movement, calculate the horizontal distances travelled by the object during the time intervals in 9 above.
11. Are the results of 9 and 10 comparable?
12. Calculate. . . [and so on up to item no. 31].

The students are thus led step by step along a narrow path. At the end, they are asked to draw their conclusions, unless the conclusions are simply given to them. When they have to draw their own, they find it very difficult; sometimes they do not see the conclusion, even though it is right under their noses. For example, a teacher told me that in studying refraction, students are led step by step to observe that the relation of the sines is constant. When the time comes to draw a conclusion, they fail to see that that is precisely the conclusion to be drawn from the experiment! In defence of the students, however, we should not overlook the circumstances in which the experiment was conducted. Nevertheless, when they are escorted so closely, we may wonder whether they can really play an active role in the process, especially since they never approach an experiment with a coherent question in mind, a problem to be solved by empirical research. The reasons offered to me to explain this lack are, "We don't have enough time for that. Anyway, they don't want to ask themselves questions. What they want is something clear and concrete. They want to be told what to do. They tell us, 'We want written facts in front of us; we won't discover them, but leave us alone and we'll learn them.' "

In fact, the actual word "experiment" has a very special meaning for these students. To them, conducting an experiment does not have the usual meaning of testing a fairly explicit hypothesis so that a phenomenon occurs in set conditions, but rather something like perceiving a fact empirically, seeing a phenomenon occur before their very eyes so as to be certain of it, as they say. Touching something oneself seems to be a measure of its reality: "It's true, I've done an experiment." As if direct experience attested to reality! One day, I asked two students working with a microscope why they were doing what they were doing. "To see," they said. "To see what?" "Things." But the teacher had already shown them. "Yes, but that's not the same, we're seeing for real"! Another time, I put the same question to two other students who were drawing curves representing uniformly accelerated movement using the air cushion disc. "Because it gets us points," they answered. A few minutes later, I repeated the questions. One of them replied, "To learn." "Learn what?" "That when you have a slope, you have constant acceleration." Did they not know that? "Yes, but we're not supposed to know it." What did that mean? After hesitating a few moments, he said, "Well, now we know it better," with a face and a gesture that seemed to say, "That's the way it is. To make sure, you have to do the experiment, hold it in your hands; anyway, that's what the teacher wants."

These and many similar incidents lead me to believe that the students (with perhaps a few rare exceptions, which my many efforts did not succeed in unearthing) have no idea of the reasons for what they do in the laboratory, apart, of course, from a few ideas about the steps to follow and sometimes a clear notion of the results to be obtained!

I discussed this with a few of the teachers. They are aware of the situation, but they do not see how it can be changed in the present circumstances. Among the reasons they cite are the fact that students' attention is dissipated among various subjects with diverse requirements; the hour-long periods are too short to allow real involvement; the programs are too heavy, perhaps, or cover too diverse a range of topics; the dilemma experienced by teachers who are torn between pursuing educational objectives they think worthwhile and teaching only those subjects dealt with in departmental exams; and the fact that "students have never learned to look, to make an effort, for they have always been spoon-fed before they even had to ask for anything." "It's the push-button generation," one teacher told me.

Exercises

Exercises are based, as a rule, on the questions at the end of every chapter in the textbook. After the teacher works out a few answers on the blackboard as examples, the students have to complete the rest by themselves, in teams (normally of two). The teacher then goes from group to group helping those who have trouble; or the teacher may stay at the front of the room so that students can come and consult him or her. Often this is a time when the teacher can make students understand a concept, law or formula that they have not yet grasped.

When a student asks the teacher a question, he or she does not always receive a straight answer. Often the teacher asks the student an easier question in return (and step by step, question by question, leads the student to answer the original question); or the teacher may give the student a more basic explanation than was asked for at first. Sometimes the teacher gives both kinds of responses at once. But students do not always appreciate teachers behaving in this way. Hence the teacher must compromise and sometimes give a direct answer.

I also observed that during the exercise periods many students were very active. They were anxious not to waste a minute; the problems simply had to be solved because similar questions would appear on the examination. When I followed the teacher's example in giving a hand to students in difficulty, they were usually quick to show their displeasure if they felt I was trying too hard to make them understand what they were doing. "What we want to know is how to solve that problem," they would say, implying that the rest was of no interest!

After questioning many students from different groups, I realized that the important thing for them was knowing how to solve problems; in other words, what trick or formula or procedure (knowing where to look for the answer in the book, for example) would work. The rationale for the trick and the meaning of what they found by using it did not interest them at all. There may be students who are exceptions, but I did not meet any. I even spoke to students reputed to be bright, who on closer inspection turned out to be very skillful at using the tricks, but showed hardly more depth of understanding than their fellows.

I also found that students often set out to solve a problem before really grasping its meaning. If I asked a student, "What are you being asked in this problem?" he or she would read the problem to me. If I asked the student to say it in his or her own words, he or she would do so with difficulty, if at all. Sometimes a student might know what was asked for, but would have forgotten the information in the statement! Never did I find a student who began by trying to grasp the problem intuitively and perceived the form and/or the rough dimensions of the solution. Faced with a problem, students begin by asking, "Which trick should I use?"

I discussed this situation with some of the teachers, who are aware of it. They offered several explanations:

> "All the students want is their marks, and the more easily they get them, the happier they are."
>
> "Students don't know how to read; they don't even try to guess the meaning of a new word. If a sentence is at all long, they get lost."
>
> "Students have a lot of trouble with mathematics. Imagine, in secondary IV, 20 divided by 12. That gives 1 with 8 left over. I hear them say, 'Sir, do I write 1.8?' There are at least 10 students out of 30 who can't do division if there are decimals."
>
> "Students are not used to having an overall view. With all the methods where they have to find the missing word, and all the multiple choice tests, they do everything in tiny stages, without really understanding what they're doing. It may be easier for the teacher to mark, but it doesn't train the students."
>
> "Students have been exposed to too many things, they've seen too much. Now they don't focus on anything any more."

Examinations

Examinations are normally held in the middle and at the end of a term. Since there are four terms in a year, there is an average of one examination per subject per month. I did not have an opportunity to be present during an examination period. What information I have on the topic derives mainly from studying examination papers received in response to a written request I made in mid-December. I wrote in my letter, "I would be most grateful if, as soon as possible, you would use the enclosed stamped envelope to send me a copy of an examination that you have given to your students recently." I received examinations from seven of the eight teachers.

Analysis of these documents yielded the following five observations. The first is that all these examinations were pencil-and-paper tests. Despite the generous time allocated to lab periods, examinations did not call for any manipulation (much less actual research). I see in this further proof that labs are considered to be nothing more than an activity which allows students to see the phenomena discussed by the teacher "for real." Furthermore, none of the questions called for ability to carry out research; for example, there were no questions asking, "What hypotheses would you formulate in the face of a given empirical problem?" or "How would you test a given hypothesis"? Obviously, something other than empirical research is being evaluated in these examinations.

The second observation has to do with the importance of memory work. In biology, most questions call for nothing but memorization. Some require definitions; for example, "Define the term 'muscle,'" or "What is an endocrine gland?" Other questions called for the converse: given the definition, students are asked to supply the appropriate term (for example, "To what do the following descriptions correspond: (1) The double membrane full of pores which surrounds the nucleus; (2) The groups of tubules arranged perpendicularly and located near the nucleus. . . ?"). Other questions entail describing the components of something, or the factors contributing to a phenomenon, or the differences between two things. None calls for reasoning.

Ecology also relies on simple memorization. There are, however, questions involving calculation; for example, given so many animals of this, that and the other species, so many plants of this, that and the other species, "What is the population of the farm? How many animal species are there? Plant species? What is the rabbit population?. . . " or "A field has an area of 8000 m^2 and is grazed by 25 cows. Calculate the density of the cow population."

The Introduction to Physical Science course asks only two types of questions on the examination — questions entailing calculation and questions calling for interpretation of charts.

The following are examples of the first type:

> "Give the solubility of the following substances in grams per 100 cm^3 of water: (1) 5 g in 55 cm^3 of water (2) 15 g in 45 cm^3 of water. . . (12) 15.2 g in 45 cm^3 of water."

A question using the rule of three (*règle de trois*):

"The maximum quantity of potassium nitrate that can be dissolved in 100 cm^3 of water at 100°C is 240 g. How many grams can be dissolved in: (1) 50 cm^3 (2) 75 cm^3. . . (10) 300 cm^3?"

An example of the second type:

"Using the charts on page 60 of your text, find the maximum mass of potassium nitrate that can be dissolved in 100 cm^3 of water at: (1) 85°C (2) 50°C. . . (10) 80°C."

Physics questions for the most part call for the application of formulae:

"A 50 g marble moving at a speed of 12 cm/s hits an 80 g marble travelling in the same direction at 2 cm/s. After the collision the 80 g marble moves at a speed of 7 cm/s. What is the speed of the 50 g marble after the collision?"

"A ball is dropped from a height of 98 m. Calculate the time taken for the ball to reach the ground: (a) 4.5 s (b) 3.2 s (c) 10 s (d) 20 s (e) 40 s."

A few questions involve defining a term (such as "inelastic collision"; multiple answers are provided for students to choose from) or understanding a phenomenon, as in the following example:

"Which of the following statements is TRUE?

A ball is thrown horizontally, at a speed of 20 m/s, from a height of 2.0 m.

A. The ball's horizontal acceleration is 9.8 m/s^2.
B. The ball's vertical acceleration is 9.8 m/s^2.
C. The ball's vertical speed is constant.
D. The ball's falling time depends on its horizontal speed.
E. The horizontal distance travelled by the ball does not depend on its falling time."

In chemistry, we find questions dealing with: (1) understanding certain phenomena; (2) interpreting charts; and (3) understanding certain concepts. One example of each type follows:

"Given a particular chemical reaction [a balanced chemical equation is given]. . . . If a particular substance is added, what will happen? If the pressure or temperature is changed, what will happen?"

"Given a series of charts representing the respective concentrations of products and reagents for a particular reaction, select the description which corresponds most closely to the situation."

"How many moles of molecules are there in 180 g of water? [The chemical formula is given.] What weight of HI (g) is formed in a mixture of 0.10 mole of H_2 (g) and 0.20 mole of I_2 (g)? The temperature and pressure are such that 20% of the hydrogen is changed into HI."

The third observation is that, when the questions do not actually call for simple memorization of terms, concepts and formulae, they mainly require students to carry out elementary mathematical procedures, such as applying the "rule of three." Overall, little consideration is given to the actual natural phenomena. Thus a student who can read correctly, carry out the required mathematical procedures and reason a little need only retain a few facts in order to obtain good marks on these examinations. (With the multiple choice questions, even less thought seems needed: a little common sense can often rule out the less probable answers and select the right one.) One may well wonder whether these examinations really assess the objectives set for science teaching or whether they measure reading, arithmetic and elementary logic skills. During the autumn I had opportunities to discuss the matter with a few teachers. They seem conscious of the problem but cannot see a good way of avoiding it. One teacher told me, "If the students had the basic skills (French, mathematics and intellectual work) and, more important, were willing to use them, we could go much farther, and do real science. But they're so poorly prepared, and they can't be bothered to work."

The fourth observation is that none of the questions deals with problems of daily life. If these examinations were the sole basis for assessing the content of the science "message," we would have to conclude that science teaching was completely dissociated from daily life. The questions do not reflect in any way the problems that may concern students nor the natural phenomena that surround them (such as a toaster that breaks down, a cake that rises, the sun sometimes turning red as it sets, the phenomenon of pregnancy, the effect of certain drugs, the manufacture of plastics and so forth). Nor is consideration given to how science may contribute to social welfare: the students are not faced with any moral dilemmas. Nor is anything said about the persons who made science or about the sociocultural context of the most important discoveries. Moreover, the connection between science and technology is not explained. The science which emerges from these examinations is disembodied and sterile. Even the style of the questions is cold and detached: X, Y, and Z are used in place of things and quantities, and instructions are given in the infinitive mood. The student is never involved in the adventure of discovery or faced with a challenge; in short, the student is never faced with a real problem that has a practical meaning, and concerning which the student could put into practice what he or she has just learned.

The fifth observation is that some questions, fortunately quite few, raise doubts about their meaning, if not about the message conveyed by science teaching. Some examples follow:

> "A large number of one cent coins are placed face down in a box. The box is closed and shaken. Predict what will happen when the box is opened."[!]
>
> "A 300 m^2 garden contains 25 carrot plants, 50 tomato plants, 12 bean plants and 200 corn plants. Calculate the density of the carrot, tomato, bean and corn population." [No information is given about the minimum spacing required for each of these plants!]

"Why does a gas enclosed in a balloon exert pressure on the walls of the balloon? Possible answer: gas is a spongy substance. When compressed, it exerts greater pressure on the walls of the container; but when the pressure is reduced, it occupies a greater volume and the pressure it exerts on the walls decreases. Which of the following experimental findings cannot be explained by this model?
1. A gas fills the container;
2. When pressure is increased, volume decreases;
3. When the quantity of gas increases, pressure increases;
4. A gas has mass;
5. When a gas is compressed and cooled, it becomes a liquid." [!?]

Conditions for Alienation

The preceding overview suggests the disquiet I mentioned at first and the existence of alienation. We need an analytical framework to guide the remainder of the study, and to permit a deeper exploration. The theoretical perspective on which the interpretation of this research is based can only be described adequately at greater length than this report permits. Readers who wish a detailed explanation may consult "Le concept d'aliénation et ses principales manifestations en milieu scolaire" by the same author. Because this model is the cornerstone of the study, we must at least present its basic outline, if only very briefly.

Alienation is a difficult topic to discuss, for there are various opposing schools of thought about it. Forced to choose among them, I have singled out the concept of "breakdown": the breakdown of a social structure established to serve a particular society. Alienation occurs when a social structure (institution, association or whatever) not only does not meet the objectives for which it was set up but also imposes a pattern inconsistent with the objectives that gave rise to it. Thus we can only speak of alienation in the schools insofar as the school as an institution makes its students and teachers function in a way that impedes young people's development, which it was established to promote.

This conception of alienation presupposes the existence of a potential that can be developed and actualized through experience, given a favourable social context. To analyze the phenomenon of alienation, I use five dimensions: structural power, functional power, intelligibility, consciousness and belonging.

Structural Power

Structural power is related to the degree of responsibility actually possessed by students or teachers with respect to young people's development in a given environment. The question to be answered is whether teachers or students can control this development within the school; to do so means being able to make decisions. If the answer is "Yes," I would assume that each group, students and teachers, would have at least the following, according to their level of maturity:

- access to appropriate information;
- decision-making power and ability to judge;
- an atmosphere of confidence and cooperation;
- attitudes such as flexibility and tolerance, acceptance of uncertainty and a sense of responsibility.

Functional Power

Functional power is the capacity to express and actualize oneself, to project oneself outward in the world of school. The question to be answered is whether our two groups can effectively actualize their potentials in the school environment. If so, as well as possessing appropriate information, I would expect that:

- both teachers and students could exercise the ability to construct, design, plan, repair, diagnose, create, carry out research, express oneself. . . and grow;
- both teachers and students would possess qualities such as a taste for some degree of risk, initiative, self-confidence, independence, perseverance and so forth.

Intelligibility

Intelligibility depends on being able to give meaning, significance to the school world. One might ask whether participants find any significance in the natural and cultural events that unfold within the school system. If they do find such significance, then I assume that they have:

- appropriate vocabularies;
- a frame of reference suitable for decoding the physical, mathematical, historical, psychological, sociological aspects of their world;
- abilities such as reading, locating and relating information, discriminating, evaluating, analyzing, synthesizing;
- aptitudes, such as critical thinking, curiosity, tolerance of ambiguity, openmindedness, acceptance of the temporary validity of knowledge.

Consciousness

Consciousness refers to the ability to grasp the effects of one's own and other people's actions, to conceive of one's daily life at school as determined by the identifiable actions performed by oneself and others. The question to be answered here is whether students and teachers can determine their place in the school. If so, it would imply that teachers and students:

- have access to appropriate information (including historical information, of course);
- possess the appropriate points of reference;
- are able to decode relevant information, interpret ordinary events and predict the consequences of their actions;
- have a perspective on events, critical judgement, a desire to know their place, social awareness, a feeling of mutual solidarity and mutual assistance, self-respect and respect for others.

Belonging

Belonging, the fifth and last dimension we shall consider, relates to the quality of contacts and relations that the two groups of actors can establish with their peers and surroundings. The question is whether the actors see themselves as people in the school world. If so, I would expect that they have:

- personal roles;
- appropriate space facilities and time arrangements;
- an identifiable peer group;
- a relaxed atmosphere of mutual respect, genuine relationships, freedom from competition and mistrust, openness to others, tact and so forth;
- an ability to express ideas and feelings in small and large groups, to appreciate other people's experiences, establish stable relationships and personalize their surroundings.

Each of the factors listed under the five dimensions can be used to analyze the phenomenon of alienation from the point of view of that dimension.

In addition to using these dimensions to judge (from the "inside") the degree of alienation in a particular situation, we may also use external indicators to identify "blind spots" within those dimensions and, consequently, further unsuspected conditions of alienation. Such external indicators of alienation can include (1) self-estrangement, (2) vandalism and the need for surveillance, (3) depression, (4) dropping out, (5) drug use.

The last four categories may not call for much clarification, but the first should be explained. Self-estrangement, as the neologism suggests, is the state of an individual who is not connected as a person with his action, who is a stranger to it; in other words, he or she acts essentially to gain a reward, not for the sake of the action itself. Thus to all intents and purposes, the action has purely instrumental value, and little or no intrinsic value. An example of a self-estranged person is a student who works solely to obtain marks, not to learn.

In brief, the model we have adopted considers alienation not as an individual phenomenon, even though it may be experienced and felt as such, but rather as a collective one: a phenomenon that varies in its scope and impact but that is always characterized by a breakdown between a given community of people and the social structure in which they are situated. Externally, a state of alienation may show itself through a certain number of indicators (self-estrangement, vandalism and so forth), but to study its essence, I have chosen five dimensions (structural and functional power, intelligibility, consciousness and belonging), each of which gives me a set of criteria to guide the rest of my study.

Following is an analysis based on those dimensions.

Analysis

Structural Power: Students

Here we are seeking to determine the extent to which our actors can make decisions in their daily lives. We shall look at the students' situation and then at the teachers'.

In considering students' power, we should draw a distinction between structural power within the classroom and within the school in general.

In the classroom, students obviously have no power at all: they can only comply with the teacher's decisions. The teacher alone decides the sequence of activities, their content, the procedure to be followed in each, the time at which they are to take place, the performance criteria and so forth. As for the actual material, the teacher determines everything (although of course he or she must meet the far-from-negligible requirements of the ministry of education and other authorities): the content considered important, its order of presentation, its rhythm, the assessment procedure and so forth. If a student asks a question outside the material laid down by the teacher, he or she usually receives a very curt answer or is told to wait until the class comes to that part of the program. In the lab, students have no choice; they must follow instructions. They are not encouraged to formulate hypotheses in response to an empirical problem (in fact, no one, not even the teacher, formulates a hypothesis). Not only are they unable to plan the steps in their observations, whether experimental or not; they do not even collaborate with the teacher in planning them. The entire process is dictated to them by the teacher, often down to the smallest details. Even the conclusion is in fact determined by the teacher: if the students do not obtain the results expected (by the teacher), that means their "experiment" went wrong, and they must have made a mistake along the way. The teacher is always the arbiter of truth (the students continually ask their teacher, "Is that correct?" "Did I get it?"). Here again, the teacher decides. Furthermore, students regularly wait for the teacher to give the answer, and simply say, "It's right, because the teacher said so." All the exercises have to be done by everyone, and they are assigned by the teacher, not designed or chosen by the students themselves. Nor do students have any more choice as regards the examinations, which are devised by the teacher and must be taken when the teacher decrees. The same rules apply to everyone.

As for discipline within the classroom, it is certainly not imposed by democratic consensus, but dictated and enforced by the teacher alone. This statement should be qualified, however, for students sometimes find ways of undermining the teacher's authority in the classroom. The following example was recounted by a teacher from his personal experience:

> "The incident began when several students were talking together during class. The teacher stopped speaking and waited for the students to be quiet. He had to wait five minutes. When he began again, he informed the students that he would make up the five minutes at the end of the period, at 3:20. When the bell rang, he was prepared to continue, but seven students got up and left even though he ordered them [his term] to stay. The next day he refused to allow these students to enter the room, telling them that he would come out and talk to them in the hall in a few minutes. Soon after the students came in without his leave: they had obtained the principal's permission!"

This does not seem to have been an isolated incident, for the teachers repeatedly complained that the rules, as they said, had no "teeth"; "If [the students] break the rules, there are no punishments." "The administration doesn't back us up, and the students know it and take advantage."

Let us continue by examining students' structural power within the general organization of the school.

This year, for the first time in many years, a students' council was elected at the instigation of one of the teachers on the student leadership committee. The council is made up of student representatives from the school's various grades and programs, elected by the students in each grade and program on 20 November. In late March the principal told me that the council had been meeting regularly (with a teacher) since November and was making suggestions to him from time to time, but the council was never consulted by the school's administration, and was not integrated into the decision-making structure of the school! Thus students have no power in the decision-making process at the school.

Nevertheless, the students do have a certain kind of power, as I discovered on one occasion. One day I was, I confess, pleased to find that the volume of the music in the hall had been turned down. During lunch hour I was sitting, as I often did, on one of the benches that encircle the hall, and, as usual, observing. I noticed a sheet of paper making the rounds: a petition. When it came close to me, I saw that the sheet had no text but bore many signatures. I heard the fellow who was circulating the petition tell those sitting near me, "It's to get the music turned up." And the students signed. After he moved on, I asked one of them why he had signed. "It takes five hundred signatures to get it changed," he said. "But who decided to turn down the sound?" "Dunno." "Did you ask him?" "No."... "What do the students think of the principal?" "They don't like him." "What do they think is wrong with him?" "Nothing.... It's because he's the principal... and you never like the principal." "Why?" "That's the way it is."

A few days later the music was back at mind-blasting level.

Extracurricular activities were introduced this year for the first time, under the auspices of the student committee. Students may, in fact must, choose one activity from among 30 or so offered, following a survey at the beginning of the year to determine which of over 60 possible options were most popular.

Students can also "choose" some of their subjects, especially from secondary IV onward, provided of course that they have completed the prerequisites. (The prerequisites are, however, comparatively easy and sometimes quite revealing. Physics 452, for example, the course offered to all those who wish to take physics, or must take it because of CEGEP requirements, requires a pass mark in Math 320. "Just scraping through" is enough, one of the teachers told me. I presumed that this was a demanding mathematics option, but my informant said, "Oh, no, just middling! They also have to have passed the introduction to physical sciences.")

At noon, if students have to stay at school, what choices do they have? Ping-pong on one of the three available tables (whose nets seem to have disappeared); ball in the gymnasium (where there are comparatively few students — perhaps 30); homework (for 10 or 20 students) in the cafeteria, for the library is closed during lunch hour because of insufficient staff, the authorities told me; or, for the vast majority, the hall, where they can look around nonchalantly, gossip with their neighbours above the deafening noise and smoke cigarettes, letting time slip past or waiting for something unusual to happen, as I observed several times. If, for example, a few students rush off in one direction, a crowd instantly follows them. Once I asked one of the few students who stayed behind what was happening. "A fight, I guess" — as if it were nothing out of the ordinary. It seems to me to be clear evidence that students do not have enough to do, at least during the lunch hour.

Structural Power: Teachers

What we have seen so far may have given us the impression that teachers wield a great deal of structural power. A closer look at their overall situation shows that their power is quite limited. In the matter of discipline (abiding by the rules), for example, as we saw, their authority is so circumscribed that, as one teacher said, "The students have the idea that everything is so mixed up they can do anything at all; for no one knows who is doing what any more in this school."

As regards the actual material to be taught, the programs and, in particular, the examinations supplied by the Québec ministry give teachers very little room to manoeuvre. They often show dissatisfaction on this score, criticizing features of the program and also the general orientation given to it by the examinations. To all intents and purposes, they are forced to train their students primarily to give suitable answers to examination questions – questions which cover only a small number of the objectives that they are supposed to pursue. Anything that is more difficult to assess, such as genuine heuristic skills and attitudes, largely goes by the board. Furthermore, because the programs are heavy and often difficult for students (who the teachers feel are too young to cope with such an abstract subject as the cinema, for example), teachers can seldom pursue sidelines such as topics of regional interest. Teachers are also concerned about what they see as arbitrary and ill-judged cuts in the program. "The ministry may have thought province-wide results were not good enough, so 'they' cut it. Now the program doesn't make sense. For instance, 'they' took cell division from Biology 412, and how can you teach evolution without that? So I put it in all the same." Teachers can, of course, make representations to the ministry, but few do so (only one teacher in this school does it regularly). For the most part, they consider "those guys are too far away. . . out of touch with reality."

Still on the subject of actual teaching, polyvalente staff suffer from fragmentation of work, a symptom that is often linked with alienation. To all intents and purposes, they work on an assembly line: one "pours in" French, another biology, another mathematics and so forth. Thus, teachers have a limited control over the product of their work and, consequently, a rather limited responsibility. Maybe a genuine cooperation between them could help overcome at least part of their problem. By "genuine cooperation" I mean something like sharing a collective view of the educational "product"; adjusting, as often and as regularly as possible, their activities with their colleagues; and defining and/or redefining constantly their short-term and long-term projects following an assessment of how the "product" evolves. Not only is this not happening, it seems practically unthinkable under teachers' present working conditions: their workload may run to 22 or 23 periods per seven-day cycle in several subjects, and they may each teach over 100 students of varied backgrounds. Low morale is also a problem, as one teacher told me.

When we move from actual teaching to view the teachers' situation in more general terms, we see a number of significant features.

There is some degree of tension in relations with the administration. Teachers repeatedly complain that the administrators do not support them. "When you spend most of your time on surveillance in the hall and the cafeteria," the principal told me, "sorting out timetables for months on end and checking up on attendance and so forth, you don't have much time left to think and to provide leadership for teachers." Moreover, as mentioned earlier, teachers do not feel that the administration stands behind them as it ought in matters of discipline. Some also complain of lack of consultation: "They [school administrators] act as if the school belonged to them," one teacher complained. "Not long ago, an assistant organized a visit by parents without even consulting the teachers. They take all kinds of decisions without consulting us."

To do the principal justice, he told me himself how he regretted his administrative overload, especially the timetables (which he told me should not be part of his normal duties, but he had to do them because no one else could) and the surveillance (he told me, "Here, I have to lend a hand so that the monitors feel I'm backing them up. We can't let up on surveillance."). Since I deliberately confined my studies to the situation of teachers and students, I have little information about the principal's situation, but I presume it is no "rosier" than anyone else's.

Let us look again at leadership. Some teachers maintain that the leadership is abysmal, but we should bear in mind a highly unusual development this year. At the beginning of the year, as mentioned earlier, some staff members (many of them science teachers) decided to set up a student leadership system, which entailed electing a students' council, organizing extracurricular activities (one afternoon every other week), assigning advisers to students (who were free to choose any teacher, within certain limits), publishing a daily news bulletin and setting up cells of about 20 students who met regularly with their adviser. The administration was, to its regret, forced to close down the cells on 11 November because of pressure from the union, the principal told me. The union also opposed the extra work created by the extracurricular activities (because teachers who happened not to have classes were pressed into supervising such activities). Despite these pressures, however, the extracurricular activities are continuing, because some teachers openly opposed the union by waiving their right to grieve the matter (a copy of a letter to this effect signed by some of the teachers was posted on the board in the staff room).

The science room occupied by the teachers who instigated the student leadership project quickly became a veritable beehive of activity. Colleagues and students were always dropping in to discuss problems connected with organizing student leadership. I felt the room to be practically the nerve centre of the school, pulsing with good humour and a spirit of cooperation. I even asked these teachers whether they were not, in the final analysis, the real power behind the school. They acknowledged that they did indeed have a great deal of power. (When I discussed this with the principal, he seemed to agree, and showed great appreciation for the commitment of these teachers. He was also pleased with the salutary effects of this and similar projects on the life of the school.) I infer that the situation in the school is in the process of improving.

To complete the picture, we should also consider a darker side of it, a side which casts a shadow on other dimensions, as we shall see: the phenomenon of "bumping." For those unfamiliar with it, I should explain that "bumping" is a yearly occurrence that lasts from late April to as late as August. It begins when a position is abolished because of lack of enrolment (due to lower birthrates, shifting population, program changes, requirement changes and so forth). The teacher who loses his or her position must then, if he or she wishes to go on teaching, displace a colleague who is teaching elsewhere in the school or school board, provided the colleague has less seniority with the board. The displaced colleague then repeats the procedure with a more junior teacher; the ripple continues until the most junior teacher is laid off. Laid-off teachers may be assigned to various teaching duties by the school administration, such as replacing teachers on leave. As the ripple — or rather ripples, for several positions have been abolished each year in this school board recently — reaches them, teachers naturally try to find positions in their own fields, but that is often impossible. Consequently, teachers trained in one subject may teach another, or they may move from the general to the vocational sector or even go from regular teaching to special education.

And every teacher is quite powerless either to halt the process or to have recourse from it. Only the most senior teachers (with over 17 years' seniority at present) are spared. But even they, like the students, suffer the very serious effects of the process on the atmosphere of the school: fear, suspicion, confrontation, discouragement – all of which profoundly affect school life, not only from April to the end of the school year, but to some extent throughout the year. Protests have been lodged with all the authorities. Everyone considers "bumping" to be the worst calamity with which teachers are faced, the biggest cause of lack of commitment and lethargy. Neither teachers nor administrators can do anything to halt the implacable machine. Even if they are not directly affected, they all suffer the fallout. One teacher told me, "Just try to talk about education in May. All anyone talks about is bumping, and it's understandable."

Functional Power: Students

Here we turn to students' ability to express and "actualize" themselves as people. Judging from how idle they are at lunch time, the students seem on the whole rather poorly equipped for self-expression. There are the few exceptions who play ping-pong or ball, and the people who change the records in the little windowless closet. But, except for the occasional film in the auditorium, no activities are organized at noon.

Viewing a film is not, however, an activity that allows students to express themselves by building, creating, designing or the like. On their own, students organize almost no activities, even though to do so would be a form of self-expression. There is little or nothing but idleness.

What happens in class? If they are not all idle, at least a good many of them are; in some classrooms nearly a quarter of the students do nothing. I did not see any class without idlers (although, of course, I did not see every single class). Another striking thing is how docile most students are, even if they are not all idle. Teachers told me, "If you tell them to go to the left, they go to the left. If you say go to the right, they go to the right, without asking any questions. And if you say nothing, they do nothing. They're not all like that, but that's the general rule." "There are lots of students who are like shellfish; you'd think they could adapt to anything." Once when I was speaking with four teachers, one commented, "The students are like zombies; you'd think they were programmed robots." The others nodded agreement, with embarrassed smiles.

On the whole, students show very little initiative. I was in a secondary III class with 22 students. They were studying the expansion of solids in the lab. They had to heat tubes of various materials one after the other by directing water vapour through them. One end of the tube was clamped to a wooden stand; at the other end, a little rod with a needle attached to it at right angles rolled under the tube, moving as the tube expanded.

I approached two students who were hard at work. At first I thought they understood what they were doing. They were, however, finishing up work that they had begun the period before.

I asked them whether they could put the needle under a different part of the tube. "Well. . . ." The student turned to the teacher, who was not far away. "Sir, could we put our needle there or there?" he asked, pointing to other parts of the tube. The teacher answered, "Yes, but it's more sensitive at the end." Soon after, I returned to something they said to me at the beginning of our conversation, namely, that the thin aluminum tube expanded more than the thick aluminum tube. I asked them why. "Well, the bigger one has more volume in it, so it takes more heat." "Sir," (the teacher was again working a short way from us) "how come the thick tube expands less than the thin one?" The teacher offered more or less the same explanation as the student, but added that if the thick tube were heated longer, it would attain the same expansion, because both were aluminum. The student turned to me, obviously pleased: "It's the way I thought." Since he did not seem to have taken in what the teacher added, I went on, "So is it the same or not?" "It's the same, because the big one needs more heat, so it expands less." "If you heated it longer, would it expand as much?" "I don't know." "How would you find out?" From a table nearby came the mocking answer, "Ask the teacher." I kept prodding my student (whose partner seemed lost in the clouds from the beginning): "How could you find out on your own?" "In a minute the teacher'll give it to us in the conclusions."

I left them for a few minutes to record the exchange in my notebook. Then I came back, to find my group's table quite bare. I asked them if they had finished. "Oh, yes." "And what did you find?" "Well, the glass tube expands less than the others." "How come?" "I don't know. We'll see in the conclusions he gives us." I asked them (though it was always the same student who answered me) what their own conclusions were. The student told me that metals expanded when heated. I asked whether glass was a metal. "No!" I asked whether they had tried with anything else, such as wood. "No." "Why?" "Well, we followed what the teacher told us." "Would you have liked to try it?" "But we didn't have time!" "Do you guys think it would have expanded?" "Yes, wood expands in water." "But we're dealing with heat here, not water." (I had forgotten that they were using water vapour to heat the tubes.) "That's so. Then I don't know." "What about plastic, would that have expanded?" "I don't know. . . . It would have melted." "Couldn't you've tried with a straw?" They both looked at me and smiled. "But we didn't think of it, and we didn't have time." The other student (finally) added, "When we do something different, the teacher doesn't like it." "But doesn't that depend on what you do?" "Maybe. . . ." The bell rang for the end of the period.

The teacher told me as I left that this was one of his better groups. He added, "You know, with 22 students, they'll do it [show initiative, seek explanations], but with 34 students. . . ."

From this and many similar incidents in secondary III, IV and V, it is obvious to me that, for the most part, students simply carry out the teacher's orders to the letter, without deviating from them and without thinking.

Let us look at another incident, which I think shows even more clearly that students operate mechanically, without really using their intelligence. As one teacher said, they are just "plugging away" without thinking.

I was in a secondary IV class with a team of two students reputed to be bright (which means they get very good marks). They were doing their lab work.

Once again I found they were following the prescribed procedure very closely. They were following the instruction, "Calculate the average of the horizontal speeds." I saw from their sheet that they had obtained the figures 3.3, 3.4, 3.4, 3.4, 3.4, 3.4, 3.4, 3.3 and 3.4. Note that these figures were recorded in isolation, without reference to specific units (I found that most students record their observations in this way; later we shall discuss this very revealing point). One of the students took out his calculator, added up the figures and divided them. While he was doing this, I asked him why he did not do the operation in his head. "I don't feel like it," he answered. When he had finished, I asked his partner to tell me what he had observed. "The horizontal speed remains constant, but the vertical speed increases." "Does it increase regularly?" "I don't know. We'll see that in question 14." At the time they were on question 5, and the set of points on their big data sheet clearly showed that the speed increased regularly.

Never did I see students involved in any project that entailed designing, planning, creating or the like, a project through which they could really express themselves. The only opportunity I had to see anything approaching self-expression — and in a very limited form at that — was when a girl in secondary IV left her class in the middle of a lab to go to the student leadership committee room next door and proudly show her mother, who was a teacher and committee member, the drawing she had just completed: the emblem of Québec! It was interesting to observe how her mother, looking relaxed and happy, studied the drawing carefully and then spoke of other matters with her daughter, who returned to the laboratory after a minute or two. I neither saw nor heard any reference to the work which should be done in a laboratory, as if it were unimportant in comparison with what she had just done! It is significant, as I discussed with the mother and her colleagues a few minutes later, that this girl seems to be perceived as one of the healthiest in the school, and that is my assessment also. Although her academic performance is considered acceptable but not outstanding, she is interested in many things (other than school subjects), is on good terms with her peers and, most important, she seems alive, she seems to have a soul which makes her radiant, instead of empty as many students appear to be. It was at this time that a teacher described most of his students as zombies.

Functional Power: Teachers

After what has been said about the effects of bumping, it is not surprising that teachers are not very keen to become involved in projects. They have not given up entirely, however, as the student leadership project shows. There is no project directly connected with teaching, however. Each teacher normally operates alone; he or she prepares "his or her courses", "presents his or her material" in more or less the same way year after year. There is no real pedagogical renewal, no actual research, no attempt to offer a new approach, no newly designed teaching material. Such things occurred in the past, but have been unknown for several years. "Why get involved in a new project, I mean a project of any scope, when you don't know if you're staying on from one year to the next? A project like that takes time and energy, and it can't be done in a year. . . . And then, think of the people who have to change subjects. They have to spend a lot of time retraining. How can you expect them to find the time — and the energy — to embark on a project? There are limits to people's enthusiasm." Another teacher told me, "People are aware that there are problems; it has to change. They [the administrators, I suppose] want us to find solutions, but they don't give us the means to find them. It can't cost anything! So what can you do?" A third teacher told me, "It's hard to do something when you don't have the parents' support. We used to have it, but we don't any more. I don't want to generalize, but there are many of us who have given up. We have more family problems than we used to — lots of separations — and also parents have less time to look after their children because they work outside the home. So we're not really encouraged. . . ."

From these comments we can see that the problem is not that teachers actually refuse to innovate, but that the context is not conducive to innovation: insecurity as to the future, the need to retrain, the lack of financial support, parental apathy. Some teachers would also add that the programs are too heavy. "There are too many things to cover in the programs for us to have time to do more interesting things. Myself, I have just enough time to get through the program, at top speed, otherwise I couldn't manage." Another factor was also mentioned by one teacher: the present timetable makes students study a different subject every hour. "If we had a modular timetable, made up of half days for example, instead of the one-hour periods we have now, heaps of projects would become feasible, because less time would be lost and the students could become more involved in what they're doing. At present, they're supposed to be involved in five different subjects a day!"

Intelligibility: Students

For the sake of clarity, we may distinguish between three levels of intelligibility. At the first level, the learning process results in students' mastery of a concrete or conceptual tool so as to have access to something real and/or to acquire the functional power to achieve an ambition. In this way, students' learning is intelligible to them. Young Inuit hunters or apprentices probably operate at this level.

At the second level, learning results in mastery of a concrete or conceptual tool so as to obtain the social and/or personal status conferred by its possession. This may be called instrumental intelligibility. Our *collèges classiques* probably used to function at this level.

At the third level, learning does not actually result in mastery of the tool but rather in behaviour that is characteristic of someone who has mastered it. In this case, the goal of learning is not the tool itself or even the status it confers, but certain behaviour patterns. If we can still speak of intelligibility, this is accidental intelligibility.

My opinion is that the students I encountered functioned on the third level, for the most part. I was in a secondary IV physics class where students were completing a film lab. I was close to the teacher, who was surrounded by students experiencing technical difficulties. A girl came and asked me whether I was a physics teacher and could help her. I said, "Maybe. Explain what you're doing." "Here, I have 6.2 and there I took the average." "The average of what?" "Well, the average!" "O.K., let's go back to the start. What did you have to begin with?" "That." She and her partner showed me a series of points recorded by the air cushion machine. "What's that?" "A URM." "A what?" "A URM." "What does that mean?" "But aren't you a physics teacher?" "Yes, but that doesn't say anything to me." "Well, I don't know!" She looked at her partner, who said, "I wasn't here when he explained it" (meaning the teacher). Both of them turned towards the group behind them and asked, "What's a URM?" Their classmates hesitated, obviously trying to remember, and then answered, "It's a uniform rectilinear motion." I turned back to the first two students, and asked what that meant. "A motion is something that travels. Rectilinear, ah. . . ." The other student carried on: "It goes in a straight line. And uniform means it's the same." "What's the same?" "The points!" "What about the points?" "Well, they're the same." She pointed with her finger to the even spacing between the points.

What strikes me as revealing here is that the students handle concepts, terms and formulae without connecting them with the corresponding physical reality, whether in physics, chemistry or biology. I have amassed enough examples to show that the phenomenon is quite widespread, and some teachers later confirmed my findings. From all indications, the students seem to think that these concepts, terms and formulae exist in a vacuum. That is all they see. These are not conceptual tools used to describe or represent physical realities; they exist independently!

In the example cited, uniform rectilinear motion is not the motion of a *real* object travelling at a constant speed in a certain direction but rather a series of evenly spaced points lined up on a page. Similarly, speed is not the distance travelled by a *real* object in a certain time, or even its value (what is obtained when the distance *travelled* by the object is divided by the time taken to travel it – and we should limit our discussion to URMs for fear of committing worse errors). Speed is simply a space divided by a time!

Acceleration — but it has to be uniform — is a speed divided by a time! The same holds true for density, in secondary III. After several labs dealing with the concept of density, a student who considered herself fairly good in the "Introduction to Physical Sciences" course told me, "Density is mass divided by volume." I responded, "I know that's how you calculate it, but that doesn't tell me what it is." "I don't know. I haven't got the precise explanation. I know it in my head, but I can't put it into words." The same is true of the concept of an average; for example, the average speed is nothing but the total of the speeds divided by the number of speeds, without any direct correspondence to a physical reality.

In biology we see the same phenomenon: as a rule, definitions are learned "by heart," without any reference to reality. One student told me, and the people around her agreed, "Biology is stuff you learn by heart. If you study [this word is regularly used to mean 'read so as to retain what is written, without necessarily thinking about it'] you get good marks." Another girl in a different class said, "Biology helps us understand the human body. I know, for example, that the body is made up of 108 bones [sic], and muscles have the properties of excitability, contractibility, elasticity and tone." I retorted, "And what has knowing all that changed for you?" With a slightly embarrassed smile, she answered, "Nothing! I know it, that's all."

The situation is scarcely different in chemistry: calculations and definitions, and little else. One day, for example, after the students had spent several lab periods weighing, decanting, filtering, washing and so forth, the teacher wrote those words on the board and asked the students to write down what the words meant. Several students then came and asked the teacher for a dictionary! I'll forego discussing students' concept of the mole!

In short, to the students' minds, science is little more than a "heap of definitions and formulae." In fact, as several teachers confirmed, any student who is good at French and mathematics and works at all will get good marks in science.

Let us look at a slightly different aspect of this phenomenon: physical quantity. The speed of a car is in "*milaleur*,"* not miles per hour, as we find when we ask a student to give a car's speed in metric units and he or she answers, as a rule, in kilometres! (A teacher told me this.) For the most part, indeed, units of measurement mean little to students, except that the teacher seems to care about them. In the example cited earlier, I asked what the student meant by 6.2. "Well, 6.2!" "But six what? Horses? Carrots?" "I don't know. It's the speed." "And what is speed expressed in?" "Oh, in centimetres"! A teacher recounted an amusing anecdote which illustrates the point well. "At the beginning of the year (in secondary IV), I asked them whether a litre would fit into the classroom. They didn't know. If I ask whether a litre of milk would fit, they have no trouble!" As if a "litre of milk" was a phrase that had nothing to do with the concept of litre.

We may even wonder whether 6.2 is deemed to be a little larger than 6. As I found several times, many students seem to deal simply with figures, not sizes. A teacher told me in this connection, "If you ask students in secondary IV or V to do simple multiplication, say 17 times 26, they may well give you an answer in the millions, if they make a mistake or push the wrong key on the calculator, as often happens. And

* A contraction of *milles-à-l'heure*. [Translator's note]

it doesn't upset them; they don't notice on their own that it doesn't make sense." Figures, nothing but figures.

To the students' minds, the presence of figures separates science from other subjects; they actually say that measurement makes it "scientific." But if measurement is not connected with physical size, it is just a hollow name. The only reason students take measurements is because the teacher tells them to. Never do they test a hypothesis; they are not even concerned with a basic problem. They "measure," or to be precise, they collect figures, which they can "play with" later. And if, as in biology, they do not take measurements, they *look*. That is what they call "observing"! In this case, the criterion for an activity being "scientific" seems to be the use of so-called scientific instruments!

Students see science as a series of statements which have already been formulated. The manipulations they carry out — for they do not make real observations (experimental or otherwise) — are designed, as previously stated, to make "certain that's how it goes." To all intents and purposes, science is thus a type of dogma transmitted by the teacher and the book. The criterion of truth for an observation is the teacher (and/or the book), not the actual physical reality. If the "experimental data" do not confirm the dogma (for confirmation is what is sought), the "experiment" must have been carried out incorrectly.

Moreover, students take note of only the most superficial part of these statements: a few concepts and formulae. They seem to take no interest in explanations or theories, even though these could help them understand the phenomena a little better. This is understandable, for explanations or theories do not figure large in examinations, if at all. Since they are not "worthwhile," they are neglected.

This science has none of the traits of a human activity. The students can barely accept that it was developed by people. Indeed, scientists only "discovered" it, as if it were always there. Neither is it localized in time or space, nor linked to a culture. Still less is it a way in which humanity has sought to make nature intelligible; it is reality in itself. No need to mention its development, except to say that science progresses by adding new truths to those that have already been discovered; science is never wrong. We shall leave aside its social repercussions, especially its relations with technology, for that is not on the program. . . .

Intelligibility: Teachers

I wonder whether teachers' perception of scientific activity does not correspond to their students' beliefs to some extent.

In the laboratory, for example, teachers strongly emphasize observation. But since they do not start out with a question to be answered, how can there be real observation? Does it not come down, as the students say, to a way of seeing for oneself, so as to be certain that it happens as stated in the book? And why do they attach so much importance to quantifying when there are not even any hypotheses to be tested, unless it is because quantification looks "scientific"? Why do they encourage students to get the right answer, instead of searching *with* them for what produced the results they actually obtained, if they themselves believe that the criterion of truth is the actual physical reality, not what they learned from an "expert"? (Teachers would say, of course, that they do not have time, but is that the only reason? And even if it were the only reason, how can they bear such a contradiction?) Why do they plan the procedures for the students, often down to the last detail, if they conceive of science first and foremost as a search for truth, a challenge to be faced, a human adventure? Again, they do not have time and there are the programs. But what image of science do they project if not the image of a completed structure? If this is not the case, how can they bear this second contradiction? And if they see science as a human adventure, how can one account for the fact that, when they "give their courses," they leave aside the essential aspect of science as a "thought seeking to understand"? Do they not also present science as a set of rigorous, bald, indisputable and rational statements, leaving no room for doubt, intuition or history, not to mention the effects of the prevailing culture at the time of a discovery. (Moreover, perhaps they misuse the term "discovery," for students think that scientific facts are discovered in the same way that vipers are discovered under a stone.) Do they not also present science as simply a description of a reality that excludes humanity rather than a convenient up-to-date representation conceived by the human mind to account for the phenomena it perceives? Thus, even if teachers' conscious conception of science is not as naive as that of their students', their actions simply do not reflect this difference.

How can it be otherwise, given their scientific training at university or in teachers' college? Since the training I see nowadays being dispensed to my university students conveys this naive conception of science, I have every reason to believe that what they received a few years ago was no different. Thus it seems unavoidable that they should in turn pass on this conception. One might also argue that they are not working in a context that favours this type of reflection. They must, in fact, act like "firefighters," always in the thick of the action, and cannot step back to take their bearings and put their work in perspective.

Let us consider for a moment these teachers as teachers, not as teachers of science. I have very little to say on this topic, for I did not devote much attention to it. I did observe, however, that the common assumption that science teachers are first of all physicists, biologists and so forth was barely warranted in their case, if at all. On the contrary, they struck me as teachers first and foremost, teachers who, on the whole, were very sensitive to their students. Furthermore, science teachers were the instigators of the student leadership movement.

The teachers' understanding of what they were doing as teachers seemed to be based primarily on the experience they had acquired over a long career (at least 17 years) in teaching, and on the whole they were satisfied with this understanding. Some of them regretted that they had too little time to bring their knowledge about teaching up to date.

Some of the teachers also regretted that, because of lack of time, money and so forth, their teaching activity was reduced, for all practical purposes, to transmitting, or "inculcating," knowledge, whereas they believe in learning through rediscovery and active student involvement. One more contradiction to live with.

Consciousness: Students

By consciousness we mean the ability to comprehend the implications of one's own actions and those of other people. "The students are very conscious of the system," a teacher told me. I agree. Within limits, one could apply to them Claire Chamberland's observations on student conformity.[1] She found her students had three types of roles: prescribed roles, adopted roles and hidden roles. The first is a role defined by students' perception of teachers' expectations, the second role is played openly and the third is played in secret because it is at variance with accepted standards. Only the first two roles were in evidence in our study. The third type of role probably does exist, but appears negligible to me, and was not especially useful as a category for study.

As regards the prescribed roles, as in Chamberland's study, the students know, whether they acquiesce or not, that a "good student" is one who gets good marks, "works," shows an interest in the subject, makes the teacher interested in him or her, shows that he or she wants to learn, in short, plays his or her role as a pupil.

In reality, a quarter of the students, the best or most docile, conform to this role, while another quarter openly refuse to do so, and "drop out" in spirit. In the middle are the lukewarm students who try to cope, sometimes quite cleverly. One teacher told me, "To get through secondary school they only have to know three answers: I don't know, I can't, and I didn't understand. That way they don't have to get involved. Because if they get involved, they may find I am pushing them further, but if they give those answers, nobody bothers them and they don't have to make an effort."

Students know that in order to pass, they have only to learn, or "retain," the capsules that the teacher feeds them in the lectures, and know how to handle the formulae correctly. In this way they will earn their marks, and that is nearly all that counts. Because students are in the habit of working in small groups, they have developed techniques for making as little effort as possible, because "what counts is what gets handed in to the teacher." So they "share" work, and thus do not have to play hidden roles. They also know that whatever they do, so long as they are within the middle range, they are sure to pass. In any case, the results of ministry examinations are standardized. "They know it, and they take advantage," said a teacher. They know what each individual teacher demands, and each student complies with it more or less, depending on whether or not the majority of the class complies. What matters is to do roughly what the other people do and, overall, as little as possible!

Students seem fairly aware of the difference between really learning and merely getting good marks. Several times students corrected me when I said, "It seems you're good at physics [or biology or chemistry]." "I'm no good at it, but I get good marks, because I study what the teacher gives us."

Without any doubt, students have an ultra-utilitarian attitude towards school, an attitude which can be seen not only in their day-to-day classroom behaviour, but also in their choice of options. With few exceptions, unless they have to take particular courses required by the CEGEP (if they wish to go there), students choose, whenever possible, the courses that are said to require the least work (such as visual arts) as these courses will still give them their "units." As a rule, they openly admit that the reason they are taking science courses is "for the CEGEP." If the CEGEP requirement were abolished, hardly anyone would take science courses.

Students are also aware of certain areas where the administration and the teachers differ as to the application of disciplinary rules, and they take advantage of this division, as has already been noted.

Students are aware that the old motivation — the prospect of a good job for those who worked hard at school — no longer holds good, for they know that young people find hardly anything in the job market.

They are aware of how bumping affects their teachers. They also perceive that traditional values are being eroded — the value of work, honesty, religion and a sense of responsibility — throughout society, and they follow the trend. They do not commit themselves, they wait.

In short, they seem to me to be quite conscious of their situation, on the whole; that now, they are the victims of a system. They have struck a balance, even though it is an artificial one. It seems to me, therefore, that their consciousness stops at this point, a rather low point because they seem unable to see themselves in a broader perspective. It would be surprising if corresponding behaviours did not persist outside the school.

Nor does science teaching seem to help the situation, as was pointed out earlier (in the "intelligibility" section). One may even wonder if science teaching, through adopting a naive view of science, contributes to this low level of consciousness.

Consciousness: Teachers

Here we should distinguish between three areas of teachers' consciousness: their awareness of the effect of their actions as teachers, their awareness of the effect of their actions as science teachers and their awareness of the effect of their actions as employees answerable to the school administration.

The teachers seem fairly aware of their students' consciousness of the system. I wonder, however, how aware they are of their own influence on students. They recognize that they themselves play a role in students' perceptions, but I wonder how well they comprehend how some of their daily actions affect these young people's development. Do they, for example, consider the effects of their emphasis (in practical terms, I mean) on marks, on examinations, on conforming, on exhibiting behaviour associated with learning rather than on actual learning? They would say, of course, that they are compelled by the system and even by the students and parents themselves, to emphasize these things. But if they were really aware of the harmful effects of their attitude, would they choose to maintain it so readily? And if they were fully aware of the issue, how could they live with this disharmony?

Are teachers truly aware of the meaning of their actions as science teachers and, specifically, of the image of science they pass on to their students? I am inclined to think that they are not. I suspect that they are even less aware of its potential to damage their students' cognitive development by producing blind submission to authority, dependence on experts, abdication of inquisitive thought, absence of genuine criticism, overestimation of rationality (other people's, to boot!), feelings of helplessness and so forth.

What of the third area, teachers' relations with the school's administration, the ministry and the teachers' union? Teachers seem to be very aware of the effects of their actions with respect to the administration, and vice versa. Even if there is occasional friction between them and the administration, teachers seem to perceive clearly what goes on and what is at stake. We may wonder, however, how far this awarenesss extends beyond day-to-day concerns. When do teachers and administrators have a chance to come together and discuss the total effect of their actions on the students, the type of education they actually provide, the ideology on which they act and the type of society they are helping to build? A committee formed to design the school's educational project did indeed produce a report recently. I was only able to skim through the report, but it seemed to deal only with life inside the school. That is a worthwhile topic, to be sure, but the report did not consider teaching as such and did not provide any substantial information about the meaning of the "message" transmitted to students by the school and teacher.

Teachers' attitudes towards the ministry appear sharply divided. On the one hand are those who see the Ministry of Education as a huge impersonal machine that dictates everything and which teachers are powerless to influence; on the other hand are those who are familiar with its workings and some of the people running it, and who act to influence its decisions and orientations.

I was surprised to find that the union, whose actions and views are supposed to be rooted in its members' needs and aspirations, was actually seen as an organization so dissociated from its members that it was liable to victimize the teachers themselves! For example, on its own initiative and without consulting the teachers, the union lodged a grievance to block volunteer work on extracurricular activities by teachers and to claim pay for services already rendered. Moreover, all teachers agree that bumping, at least as it occurs at present, is a pointless exercise, for in the end everyone suffers. But even though they would like to see it abolished (as would the school board), they do not know how to go about it! Thus even the union has become a factor in alienation.

Belonging: Students

A person who "belongs" is aware of himself or herself as an integral part of his or her environment and is in touch with others who share that environment. As a rule, teachers and students do not use the formal "vous" in referring to one another, and everyone is on a first-name footing. Relations are rather cordial and sometimes quite familiar. At first sight, then, the distance between the two groups is not as great as it used to be. It would seem that relations between students and the administration are equally close (at least on the surface, for we should remember the student who said that the principal isn't liked, because he's the principal).

Furthermore, since the student leadership project was introduced, students and teachers have more opportunities to get together, at least in theory. Since the union's legal action took effect on 11 November 1982, the cells in which 20 or 30 students could meet with their adviser in a regularly scheduled period have had to be disbanded. All that remains is individual meetings arranged by the student or the teacher. But because there is no "slot" for such meetings in the timetable, which is already very full, the meetings must be held on the run, between two consecutive periods, or in time stolen from student's class time. This is sometimes done, but as one teacher said, "We mustn't do it too much." It is not possible to meet after school because the school bus system (the "yellow peril") will not allow it.

In class, some student-teacher contact is possible, but it is restricted by the volume of "material to be covered" and the number of students (20 to 33 per class). Moreover, since a student spends only three to five hours a week in contact with each teacher (he meets five to seven different teachers a week), the potential for real contact is further limited.

Some degree of contact with classmates is possible, but a student mixes with so many in his various courses (roughly 100 in secondary IV and V, though somewhat fewer in lower grades) that close bonding is hardly fostered. Bonds may, of course, be formed over the lunch hour, but we have seen how idle students are at that time of day.

The fact that students have to move from classroom to classroom and have no real meeting places apart from the hall, the cafeteria and the ping-pong room (all three of which are as noisy as they are impersonal) and the gymnasium and library (which are reserved exclusively for sports and reading and draw very few students) definitely does not help to develop a feeling of belonging. With what can students identify if there is nothing they can shape in their image? There are the murals in the corridors, but they are several years old by now. What is left? As far as I can tell, there is only the music! The music in the hall at lunch time, morning recess and immediately after school. I find it symptomatic that students insist so strongly on such loud rhythmic music. Is it to meet their need for escape and self-assertion? Because they cannot make their walls more personal, they claim possession of space through their music — indeed, they attack the whole school! A pity I was not there when the amplifier vanished, for I would have liked to study how the absence of music affected the dynamics of the school.

Finally, because bonds of friendship often grow in shared work projects and there are no such projects (or very few of them) in or out of class, we may wonder how much the school really wishes to develop such bonds.

Belonging: Teachers

Turning to the teachers, we find that most of them look for contact with the students — a matter of vital interest to some teachers. But, as mentioned when we discussed the situation of the students, there is little opportunity for real contact. We should consider, too, that each teacher meets with over 100 students a week for a very few hours. How could they have time to come to know their students well? They may know some of them, perhaps 10 or 20 or maybe even 30, but certainly not 125.

Among themselves, teachers develop some bonds. But unless their offices are in the same place, they have few chances to meet. Even for those working in the same room, these bonds only infrequently lead to real collaboration. Everyone tends to work alone. I even noticed traces of distrust between teachers, slight but unmistakable. (I am inclined to attribute this to the general climate of the school and the effects of bumping.) Teachers are also somewhat distrustful of the administration, although these relations seemed fairly cordial on the whole. At least some teachers and administrators seem able to speak very frankly to one another.

With parents there is almost no contact. Once a year a parents' night is held, but very few parents come (about 15 per cent at best, according to the staff). Those who do attend are usually the parents of students who are doing well.

Relations with school board officials are almost nonexistent. "They are far away, and they don't know what's going on here. They should come and take our place now and then, that would bring them down to earth," a teacher said to me. This does not mean there is confrontation, but only lack of support. With one exception, the teachers have no contact with the Ministry of Education. All contact is one-way, through official documents.

We should say something about the rooms where teachers work. First, there are the laboratories. Because all their courses are "given" (to use the teachers' term) in one of the seven laboratories, and normally each teacher keeps to his or her own laboratory (except that sometimes two teachers share a laboratory), one might expect to see a teacher's individual stamp on each room. On the contrary, the rooms are almost all equally impersonal. The same is true of the three staff rooms: there is almost nothing to identify them. These rooms have been taken over by laboratory equipment, so that the teachers are practically working in a storage room. In my view, the state of the laboratories and the staff rooms points to the absence of a feeling of belonging and also to the downplaying by the administration of the teachers' need for identification, even though that is quite a basic need.

In the same connection, I feel it is significant that social activities are very poorly attended by teaching staff. One teacher told me that when a party is organized, "You see barely 20 per cent of the teachers, and always the same ones."

The Indicators of Alienation

I began my discussion of alienation with the idea that when a social system like a school functions in a way that impedes the very development it was intended to promote, a condition of alienation may then exist. Taken together, several potential sources of alienation may help us understand why students and teachers place such a stress on instrumental rather than on intrinsic sources of satisfaction (leading to self-estrangement) and why students and teachers "tune out" of their world. Self-estrangement and dropping out, which we have examined in detail, are only two indicators among several of a state of alienation. It is reasonable to think that vandalism, depression amongst teachers and students, and drug use are also evidence of a state of alienation. We have only obtained limited data on these matters. Although vandalism has reduced considerably, there are still many instances of it, and the degree of surveillance is also significant. As regards depression, the principal and teachers had different perceptions, the latter claiming that the phenomenon was widespread among both teachers and students. "This is the first year," one teacher confided in me, "that I have seen so many depressed students," and his colleague added, "I estimated that depression affects 15 to 20 per cent of the teachers, and that only includes severe depression." As for drug use, it appears to be on the decrease, but we have no data with which to examine this situation further. More research is needed on this point.

Self-Estrangement or Instrumental Values

It is obvious — and the teachers acknowledge it — that the students' primary motive with regard to science courses is to obtain marks. Nearly all their actions are dictated by the hope of getting marks, because these will enable them to get their "units." (To earn a diploma and qualify for a CEGEP, students must complete a certain number of units, and for some CEGEP programs, they need units in particular disciplines.) When they are no longer concerned with these units, they drop out, in body or spirit. This is readily apparent from their thoughts and general behaviour. They are very docile in carrying out tasks set by the teacher: "I've got to do it because the teacher said so," "I'm doing it because I want my marks," "I need it to go to CEGEP." Other forms of behaviour are also revealing: the feverish activity of some students in labs or exercise periods, for example, where they are basically trying to finish work as quickly as possible "to get their marks." The fact that students do this work without really trying to understand what they are doing is symptomatic of their obsession with marks. As a rule, students do not pay much attention to the teacher's explanations, unless he or she is giving technical information relevant to the work, and hence to the marks.

The teachers continually deplore the fact that "students no longer want to make an effort; all they want is to get their marks as easily as possible." One teacher told me: "Nowadays you don't see effort and work. You have to make an effort to understand; the students don't any more, and the [academic] results show it. . . . The future doesn't motivate them any more, though before, people used to work for the future. They trust the standardization of marks. The administration even tells us that some of [the students] are only there for looks. . . . For a gang, the threat of marks and the promise of something more positive means nothing. Since students are very easily led, especially the youngest ones, the others are tempted to imitate them; repeaters are often looked up to as heroes! Ten or 15 years ago, even the dummies tried to make an effort."

This last point, the absence of effort, also seems to me to indicate the instrumental significance of the students' actions. The "law of least effort" surely comes into play when an activity does not have enough intrinsic meaning, when it is only a means to an end, a desirable end. Of course, each of our actions always has a mixture of intrinsic and intrumental value. But if intrinsic value predominates, the concept of effort and hence the "law of least effort" are irrelevant. If instrumental value predominates, on the other hand, effort is a factor to be considered, and the least effort is given. Consequently, I do not think the absence of effort is blameworthy, as the teachers do, but is rather another symptom of alienation.

There would seem to be, in effect, two realities in the school: one implicit and the other explicit; one based on experience and the other based on intentions. The marks game belongs to the first, the unspoken reality, while the action which is supposed to be directed at learning, developing research strategies, developing logic, reasoning and so forth belongs mainly to the second, explicit reality. These two realities are generally seen as existing side by side, by both teachers and students. Talking to me or to their students, the teachers emphasize the second reality. But in the way they run their classes (saying, "You have to hand this in to me by the deadline" or "The ministry examination has this three times out of two [sic]"), and by the very form and content of the examinations, they give clear priority to the first, unspoken reality, for, as they all say, "We have no choice." The students give obvious priority to the first reality ("I'm doing this because the teacher told me to" or "to get my marks" or "to get through my work"). Very seldom did I hear anything like "I'm doing this to learn." But for students the word "learn" has a very vague basic meaning, and is essentially intellectual (in that it does not really express a fully conscious experience). It serves as a justification that sounds good, and echoes what students have heard their teachers say many times over. It is not a reason for action grounded in personal experience.

Teachers and students seem to be living in two worlds and seeking to come to terms with a basic contradiction. Those who fully accept the unspoken reality, the "drop-ins," adapt to the contradiction by striking a kind of balance which, though artificial and temporary, seems to suit them fairly well. The others feel hemmed in, uncomfortable and dissatisfied. They may react in two opposite ways. Either they may drop out, literally or in spirit, justifying their actions in their own terms ("School is boring, I can't wait to leave"; "It's the other guys' fault, the ministry's or the teachers' "). Or else they may discharge their meaningless obligations and go on hoping that sooner or later the picture will change and it will all be more interesting.

In the meantime, they taste very little of the fruits of their labours (the satisfaction of knowing something new, the pleasure of mastering a new tool, the pleasure of meeting a challenge, the satisfaction of achieving something of value on one's own, whatever it be); they get marks! They are thus locked into a situation like that of the worker, lamented at length by Marx and others, who is denied access to the produce of his labour and receives only a few "green slips of paper" of token value.

The situation is still worse for students motivated primarily, if not solely, by the desire for good marks. Unlike a worker who can immediately exchange his token slips for the goods he wants, the student is a worker whose services are rewarded by a slip of paper that may, if conditions are favourable at the time — and these conditions depend not only on the student but also on imponderable and sometimes arbitrary factors — give him or her an opportunity to work at something else, which the student hopes will be more interesting! If we are ready to believe that workers are alienated, even though they can enjoy the results of their labour indirectly in the very short term, we should be even readier to recognize alienation among students, who have to work for nothing but marks.

Let us now turn to the teacher. One afternoon, I was in the science teachers' room, talking with a teacher about how he regarded his work. He had just received the computerized results of the last examinations. They were pitiful: 20 per cent, 30 per cent, with only a few 70s or 80s. The problem was not confined to his own subject, for he showed me the marks for other subjects, which were hardly more encouraging. At one point he said, in front of a few colleagues, "The longer this goes on, the more I feel I'm only here to get my pay. I have to present the material. You can take it or leave it, I don't care. I think it's serious when you get to thinking like that. I'm sure it's common; most teachers think that way." A few minutes later, in the same conversation, I asked another teacher who had been listening to us, "In the end, is the pay the only motivation?" "That's practically all that's left, along with job security. . . . After a while, you get hardened to it; you take it one period at a time."

Still in the same conversation, I asked them whether there was not a sort of tacit agreement among them to avoid the questions we were discussing. They agreed that there was, with a rather embarrassed smile. One added: "We each have our escape hatch. Mine is do-it-yourself work. At home, I go down to my shop and putter about. It helps me forget." Another said, "The worst is when you don't feel like doing anything any more. If you can't find anything to do, you think about it all the time; and that's bad." A few minutes after this conversation with the three science teachers, the lab technician, who had listened to our talk in silence, told me that at this time of year (early December) the teachers were tired and subject to depression, while at other times they were less pessimistic.

Immediately after this conversation, I went to another place where I found two other science teachers with a woman teacher from another discipline. (These teachers are very interested and caught up in a student leadership project they have been working to set up since the beginning of the school year.) As usual, I found them full of enthusiasm. Nevertheless, I asked them what would happen to them if they did not have student leadership. They all said without hesitating, "Depression!" For them, student leadership seems to be the "escape hatch" to which the other teacher referred. For it is important to note that this work is supposed to be incidental to their real job, which is teaching science.

Tuning Out

We can also begin to understand why students "tune out" by thinking of this behaviour as a symptom of alienation. In nearly every class there are two or three students who do nothing at all, and are only there for "looks," as one of the teachers said. "They're waiting to be old enough." These students seem to influence some of their classmates, for one teacher told me (and a colleague who was talking with us at the time confirmed it), "You know, we used to have regular bell curves in our classes. Now there are inverted curves: only very good and very poor students. It's the same in every class: math, physics or whatever." Dropping out in spirit, or "tuning out," seems to be a fairly widespread phenomenon.

The absentee rate also struck me as rather high. The principal still did not have the statistics for the current year at the end of March, and could not tell me whether there were more student absences in that year than in previous years. He estimated the rate to be five to six per cent, as compared to an acceptable rate of three to four per cent. He believes, however, that the school attendance committee which was set up recently to monitor student absences, should make a greater effort to lower the rate. The science teachers, for their part, think that the absentee rate is seldom over one per cent in their classes.

Teachers seem to be rarely absent, but their absentee rate rises noticeably in February and March, according to the principal, because of fatigue and early spring depression. Personally, I was surprised to learn of several instances in the fall when teachers took a half-day or day off "to rest," as if it were almost an accepted custom. However, I am unable to judge how widespread the practice may be. The principal confided to me that when a teacher has used up his or her statutory sick leave, he or she could be expected to stay away longer, knowing that the bonus that would have been paid at the end of the year had been lost. The work does not seem to inspire teachers greatly. Moreover, teachers told me several times that, to their regret, teachers tended to "disappear" when they do not have a class. (Note, however, that this practice is allowed under the teachers' collective agreement.) This behaviour seems to me to be further evidence of disaffection. I should add, however, that I have found science teachers working hard outside their class periods, some of them quite often. Perhaps science teachers are less given to wandering off, but the practice does exist.

There is also wasted time to consider. This is a conspicuous phenomenon which both students and teachers seem to accept as normal (but can be regarded as a form of "tuning out"). In addition to the five or ten minutes lost at the beginning and the end of each period, time is wasted during all the time when students' minds are far away. More time is lost in making "fair copies" of laboratory procedures, for instance; in doing nothing while the harassed teacher finds an answer to a student's question (that the student could probably have answered for himself or herself, if he or she had made the slightest effort); time wasted at the end of an activity because there was not enough time left to begin another; time lost in team work. I noted a typical example of unproductive teamwork in my notebook as follows:

> "I am in X's class. Everybody is hard at work (an exercise period or the end of a lab?). I hear background noise here and there, zero point something, zero point something else, chairs moving, occasional laughter. . . . I go quietly up to a group of three students absorbed in their work. One is dictating data, another is working out figures and writing them down, and the third is eating licorice!"

There is also much time lost at the beginning of the school year, even though this year (for once!) there was no strike. For example, several teachers expressed dissatisfaction because the secondary II and III timetables were revised late, so that some classes could not get under way until the very end of September!

We should also mention the time that is wasted when teachers are absent temporarily and are replaced by supply teachers brought in at the last minute, unprepared to carry on the regular teacher's work. All too often, in the teachers' view, supply teachers are unavailable.

Postscript

In my view, students' instrumental values and "tuning out" are symptoms of a state of alienation. This view is supported by the preceding analysis. Though I am well aware that such a conclusion is quite controversial, I have tried to be as circumspect about it as possible and explain to the teachers how I arrived at it. To ensure that the facts were representative and the interpretations correct, I decided I had to give the entire report to each of the eight teachers who figured in the study. They met with me to study my report page by page. The meeting was held away from the school and lasted a full day. Only one teacher was absent.

The teachers did not ask for any major changes to the original text. Their comments were used to flesh out some passages and slightly alter others. Therefore, the picture of the situation painted here has the unanimous support of the actors in the research, who consider it a faithful and representative account. They wished to emphasize, however, that the report describes the situation prevailing in the fall of 1981. They consider this an important point because the situation changes somewhat over time: the program content is altered, teaching procedures are revised, the students become more mature and experienced, end-of-year pressures and spring fever show their effects and so forth. Still, the general life of the school remains largely the same (except that the bumping cycle peaks at one point during the school year).

The teachers as a group formulated a number of comments and asked that they be included in my report:

> "At present there are very few (too few) connections between the various secondary science programs, except that the secondary V programs follow on from the secondary IV programs in the respective disciplines.
>
> "This year, as in the past, we have found that in secondary V science, students' abilities and attitudes improve substantially throughout the year. Not infrequently, some of the students suddenly become "clued in" during the second term. On the other hand, others tune the material out when they find that the CEGEP program they have decided upon does not require the course they are taking.
>
> "Two other issues deserving attention should be added to those mentioned by the author in the conclusion to this report. The possibility of bringing together students working at nearly the same level in one polyvalente should be studied, with a view to having more teachers in the same subject so that they could set up work teams; and the possibility of promoting a feeling of belonging among students and teachers, and continuity between some subjects, by having one staff member teach several related subjects (such as the different sciences and mathematics) to a few groups of students should be studied.
>
> "Your work among us and your report have made us more aware of how we teach and under what conditions we work. We felt these things, but now we can put them into words. We have also become more conscious of the objectives we are or are not pursuing. The study also helped establish bonds between us.
>
> "Next year we plan to introduce changes at our level. We hope, however, that the publication of this report will instigate further changes at higher levels."

Some teachers said they felt the final report did not go far enough. They thought its fine shadings and qualifications did not bring out the gravity of some situations clearly enough. Since I wished to steer clear of alarmism and polemics, I preferred to keep the report in its present form.

Readers who teach science in a different environment are certain to find that their situation differs in several ways from the one described above. This is to be expected. But I wonder whether they may not also recognize overall and underlying similarities.

Of course, these similarities may be difficult and unpleasant to recognize. But only when the sources of alienation are identified can we try to change the situation. The considerations I have grouped under each of the five dimensions used to analyze the phenomenon of alienation might be the basis for constructive change. Ways of improving teachers' and students' structural and functional power, intelligibility, consciousness and sense of belonging could be studied. I shall not go into the details of the changes that could be made, but I would like to point out a few major issues that I believe deserve careful consideration.

Issues for Deliberation

It is very obvious that the practice of bumping should be reappraised. I do not know enough about the matter to put forward a sound alternative to it. Could exceptions not be made, however, at least for teachers engaged in innovative teaching projects of a certain scope? Such an exceptional measure could stimulate the continuing improvement of teaching.

I also wonder whether it might not be advisable to study the present timetable format and consider the feasibility and advantages of introducing a modular timetable (with half-day periods, for example). Such a timetable would necessarily entail substantial changes in class organization but would probably involve students more in their work.

We should not, of course, assume that changing the organization of classes would improve the quality of learning; changes in students' and teachers' attitudes are even more important. It might be useful to thoroughly re-examine the place of inquiry in learning (for students) and teaching (for teachers). I do not wish to imply that the student should find out everything on his or her own; to do so would be utopian. I am only suggesting that, at least at the beginning of some of the basic units of material to be explored, the student should have the opportunity to test and hone his or her research abilities. Things subsequently learned (the rest of the "chapter") could then be reconciled with what the student has already discovered for himself or herself, even if this process results in contradictions. I am aware that I am simplifying here, and this approach must be thoroughly developed before it becomes acceptable; moreover, it has its limitations. Nevertheless, I believe this is a path to be considered.

With regard to teachers, perhaps their status as "distributors of information" could be altered so that they too could become involved in inquiry into the subject of teaching itself. I wonder whether such a change, together with more opportunity for contact with students, might not increase teachers' motivation to teach. This would presuppose several changes in teachers' working conditions, such as the possibility of taking sabbaticals, the possibility of setting up research teams (which would include university teachers, for example, but also regular staff members) and lighter teaching loads. I know these changes cannot be made without others, and will not be easy to achieve, but I think they at least deserve to be considered.

Might it be possible to bring teaching material much more into line with students' daily lives? This does not mean that education would be reduced to a cafeteria smattering of natural and/or cultural phenomena selected at random, but rather that certain subjects of study (to be determined) would be tied to students' experiences in the real world. It would also mean that teachers would try to involve students in projects that would make the learning experience more concrete. Obviously, this approach would entail major changes in the programs. Students would not "cover" as much, for example, but at least they might learn something meaningful and useful, which is perhaps more than they learn at present.

Also, should we not consider overhauling examinations so that they correspond more closely to the objectives science teaching is supposed to pursue? At present, most examinations serve primarily to assess how well a student has retained (not necessarily understood) certain data, and how well he or she can apply a set of "formulae." Others appear to measure only how well a student has mastered the technique of answering multiple choice questions! I know how difficult this problem is to solve , but I think that the quality of education seems to depend on it.

In the same vein, perhaps the impact of the "marks game" could be softened so that the symbolic importance of marks did not impinge on actual learning; for example, marks might be given more for a student's achievements — as indications of heuristic capability (skills and attitudes) — than for the student's ability to conform and follow instructions. I am not saying that knowledge as such should be set aside, but I think it should receive less emphasis, at least in theory; for in reality, knowledge is often only a thin varnish that must be renewed every year, and sometimes completely replaced!

Lastly, should we not give prominence to the human side of science? By this I mean giving attention not only to the people who have built up and are building up science, and their cultural milieu, but also to the positive and the negative social implications of science (which often result from technological change). I agree that it may be difficult to distinguish clearly between the "positive" and "negative" effects of science. Yet I think that it would be educational for young people to be exposed to matters of this kind from time to time. It might contribute to their mental development and, in particular, to the development of a measure of social consciousness. I know these suggestions are not original ones; but viewed in the light of my findings in this study, they may have some value.

In closing, I would like to express my deep gratitude to these teachers and their students for letting me learn so much through contact with them. This study allowed me to immerse myself in a real-life situation and has inspired me to become more involved in the day-to-day teaching of science. I hope that this report will contribute not only to improving science teaching but also to the general education of young people in our polyvalentes. If it does, I shall feel that the trust placed in me by the students and teachers at this school has borne good fruit.

Notes

1. Claire Chamberland, "L'étudiant conformiste et l'enseignement du français au CEGEP: Une étude de rôles," *Recherches sociographiques*, September-December 1980, vol. 21, no. 3, pp. 283-316.

IX. Science at Prairie High School

Glen Aikenhead

The School

The students of Prairie High come to grade 9 from a kindergarten-to-grade-8 elementary school. For these students, Prairie High represents a totally new social setting, involving 500 to 1000 students. Events, such as wiener roasts and dances, are held to welcome the newcomers and ease their transition to Prairie High. The students come to the school from well-established middle-class communities. Their behaviour in the corridors is courteous, even jovial at times. It was always pleasant for me to flow with the crowd during class breaks and to be acknowledged by students who took it upon themselves to say "Hello." During the day, students can walk or drive to a nearby shopping area. While some students "escape" from the school at the first possible moment of the day, many make the school their social focus. The school offers a large number of extracurricular activities such as sports, fine arts and clubs.

More accurately, perhaps, the teachers offer these activities. Teachers are expected to lead several extracurricular activities for two or four hours per week. These responsibilities are in addition to other activities these teachers are normally expected to carry out, such as planning instruction, gathering materials within the school and outside the school for science labs, assisting students by giving extra help with their studies or with science fair projects, serving on professional committees (within the school, provincially and nationally), and administering charity projects in cooperation with students. Classroom teaching thus constitutes only a portion of the teachers' daily workload. Teachers also gave freely of their time to participate in this case study, increasing the already heavy demands placed on them even further. Yet not only did I sense that the teachers accepted me, I felt genuinely at home in their school. Factors that contributed to this feeling were their curiosity and enthusiasm for the case study from the very beginning, their willingness to let me join their classes at any time without notice, their ease in talking candidly and perceptively about their teaching, and their thoughtful analysis of the classroom events that we shared.

The teachers in this study are no strangers to the classroom. Their experience at Prairie High ranges from five to 22 years, with the majority having more than 10 years' teaching experience. All but one of the teachers have a Bachelor's degree in education and three have Bachelor's degrees in science as well. Two have Master's degrees in education while one has a Master's degree in science. Some teach mathematics, English, arts or geography in addition to their science courses. Others, who teach the senior physics, chemistry and biology, also teach grade 9 physical science and grade 10 chemical science. Class sizes range from 14 to 34 students, averaging 27 students per class, and most classes have equal numbers of boys and girls.

With only one exception, provincial curriculum guides were conspicuous by their absence in all discussions with the Prairie High science teachers. Teachers have adapted these guides to suit their own practices; the one major exception to this settled adaptation of curriculum guides was the grade 10 course. The province has recently adopted an approach to physical science that emphasizes chemistry, and this new syllabus has replaced a variety of grade 10 courses throughout the province. The new text for grade 10 is *Physical Science: An Introductory Study*. One teacher thought it really did not matter how the grade 9 and 10 curriculum was written, or what approach was taken, as long as the students were doing science. Another expressed dismay over the new curriculum and the experiments in the textbook that did not work out properly. However, he liked using the text because, in addition to science, he taught reading skills, such as the ability to abstract the "key idea" from a paragraph. In some classes the text was followed closely ("because I'm going through it for the first time"), while in most classes it was used as a point of departure. In all cases, the text was used very differently by each teacher. One teacher said that he supplemented the textbook "with the atmosphere in a classroom, his personality and his background." He did this to such an extent that some students felt he was "too smart to be a teacher."

The science teaching staff at first hoped that this case study might serve as an assessment of their science instruction. This expectation had to go unfulfilled. Assessment of individual teachers was not possible because the case study was not planned to be a case study of individual teachers, nor was it planned to be evaluative. Instead, it is a case study of science teaching at Prairie High School, with each teacher contributing episodes to the total case study. Each episode is like a small fragment of coloured glass; when many are assembled, a mosaic may emerge. The picture cannot depict one teacher's instruction because the picture is an expression of the whole.

Similarly, there isn't just one approach to science at work here. In Mr. Epp's grade 9 class, for example, an introductory section on "What is Science?" dealt with the assumptions made by Aristotle and Galileo. But then a discussion developed into an analysis of the logic and assumptions of current television commercials. "If you apply the scientific method, you will see through these commercials," Mr. Epp concluded, in attempting to relate science to everyday life. Down the hall another grade 9 class was instructed to read the same passage and to begin the first lab in the text. Mr. Bews had decided not to discuss the passage "because the students have had it all before," and he felt strongly that the students ought to get involved in science as soon as possible by doing a lab. Mr. Epp had not prepared the "Burning Candle" lab that day, while Mr. Bews had not monitored student understanding of the passage. Each teacher's decision to select a particular approach came from a different perception of how best to introduce grade 9 students to high school science. Each teacher provided his students with a very different experience based on the same textbook passage.

This report reflects what all the teachers had to say about significant issues for science education; as we shall see, they spoke with diverse voices. Reflection on these issues has meant probing the conscious and unconscious decisions they made and, at a deeper level, analyzing the beliefs and perceptions that guided their decisions and even dictated their objectives. My task was not to make sense of the classroom events that I saw; it was to get the teachers themselves to make sense of these events. My ultimate purpose was to permit the reader to understand science teaching better from the teachers' point of view. To do this I have organized the teachers' comments and reflections under a number of headings. These headings reflect a balance of interests; some of the topics were of greater interest to the teachers; some were of greater interest to me. All are significant, I believe, for science education at Prairie High. The story begins with what may be the most important issue for the teachers — coping with the range of student abilities they find in their classes.

Teaching Science and Students' Abilities

The science classes at Prairie High are streamed according to three levels of students' abilities, and teachers hold different expectations for these different classes. In all science classes at Prairie High, students worked from the same textbook, regardless of the ability level of the class. There were a number of advantages to this practice, including ease of student mobility from level to level, ease and efficiency of teacher preparation for classes at each level, and a basic belief in the value of the content of that text.

Mr. Dareichuk's "bright" grade 9 students studied significant figures during two classes of meticulous algebra practice. His students were expected thereafter to state observations in a form called "scientific notation" (where 6100 metres becomes 6.1×10^3 metres). Mr. Dareichuk compared this same instruction to his instruction of an "average" grade 11 physics class:

Aikenhead: What was the reason behind the decision to use scientific notation and exponentials with 9th graders instead of using the strategy you used with the 11th graders?

Dareichuk: For one reason, they should be more capable. And secondly, they're going to be, probably most of them will be, ones that will make use of those facts much more, later. And so, therefore, their knowledge is much more exact.

Aikenhead: Does this affect the way you design your tests?

Dareichuk: I have to be careful not to put any real thinking questions on the test. It's just very simple, almost very similar to what they've done in class; otherwise it really bothers them. . . . They wouldn't touch these [application type of questions] because it would be foreign to them. "What do I do?". . . You've got to lay down sort of rules; "Here's how you should form this so it works well." And then you get fairly good results. I've laid down the rules for them; say if you're doing convex/concave mirror calculations; I've sort of laid down steps that they should try and do so they get that process going. So I give them four or five steps where I said, "O.K., now when you're doing concave mirrors, what does the question ask? Draw your diagram, put on the different parts of the measurements we're working on. Which ones do you know the values for, which ones don't you? Let's make a list of these. What do you know; what is asked for?"

This step-by-step precision was noticeable in Mr. Dareichuk's grade 11 physics class where 30 students, about an equal number of boys and girls, sat in pairs at tables watching him at an overhead projector with a triangle-shaped piece of glass. The materials for the lab were in front of each pair of students: cardboard, pens, glass triangle, a mimeographed sheet with the outline of the glass triangle giving the students explicit directions where to place the triangle on the sheet.

Mr. Dareichuk pointed out that the two angles chosen for the experiment will give good results by not confusing internal reflection, and showed how to set pins into the cardboard surface to define rays. He sketched on the overhead projector what the results of the lab should look like ("just to show you how these rays are going to work in general"). He then had students predict what bending of light should take place, based on the students' past work with water. Finally, he reviewed the geometry constructions and the mathematics calculations that students would do with their results in order to calculate the index of refraction twice, on entering and on exiting from the glass.

The price teachers pay for not making every detail clearly explicit is student confusion. Mr. Almon's grade 9 "average" class assembled equipment for a pendulum lab without reading the lab instructions, in spite of Mr. Almon's unambiguous directions to read these instructions right there in class. He found himself moving around the room from group to group repeating the same directions, causing students to wait to have their procedures corrected or for guidance on how to begin. When asked if doing the lab as a demonstration might have overcome the problem of students not knowing what to do, he made these comments:

Almon: I don't like that kind of experiment, in general. There are some experiments that are so difficult that you have to do it that way, or the class is of so low a level. For example, if I had a totally low-level class, I might have to try that with them. I guess that defeats the purpose of an experiment in some cases.

Aikenhead: In what sense?

Almon: Well, they're not inquiring on their own, you know. I'm inquiring for them [and] they go through the motions, but it doesn't go through their heads. Also, I really want them to read instructions. And they have improved on that. I've seen a marked improvement on reading and listening to instructions I give them.

There seemed to be a constant compromise between achieving ideals — in this instance, inquiry — and matching instruction with students' abilities in order that they might improve in some obvious way. Mr. Almon was willing to invest the time with his "average" class, but predicted that it would not be a wise investment for a class with a "low level" of ability. There seemed to be a critical balance between mildly challenging students and overwhelming them.

Epp: You see, this is the dilemma you're in. You stand up in the class and you explain to them what the observations are [in a lab], and what the conclusions are. And yet when they go to write their lab reports they don't do that. They have something altogether different. Whether they haven't been paying attention or whether they think theirs are right, I don't know. But they all should be handing in the same lab. I'm trying to help them, but they're not listening.

Mr. Epp did not see any way out of his dilemma. He did try with all his energy to help students, but some would get it wrong anyway.

An interesting opportunity presented itself when I was able to observe how teachers put their ideas about coping with different ability levels into practice. I was able to observe variations in the same lesson taught to three ability levels when Mr. Cheney introduced his grade 11 biology classes to classification. Students had previously collected insects. (Higher-ability students had brought in one insect from each of 10 orders, while lower-ability students collected fewer; that is, they had the same assignment, but different things were expected of them.) The lesson had four major parts: copying definitions from the board (kingdom, phylum, class and so on); discussing the classification of everyday objects as a characteristically human activity; applying these ideas to how common things are classified (for example, a telephone directory, volleyball players and products in Safeway), thereby explicating important characteristics of the classification process; and using the household mutt, *Canis familiaris*, as an example of genus and species, then family, then order and so on.

All students kept on task for the whole period in spite of interesting distractions such as large coloured photographs of flowers covering one wall and, on another wall, body systems charts hanging above shelves of reference books and specimens – both pickled and stuffed. Equipment littered the workbench that extended the full length of the room. The room was visually exciting and was without doubt a biology classroom.

The first class I observed was an "average" group. After the class, the teacher and I briefly talked about his plans for that day, specifically for the low-ability students:

Cheney: That's something that isn't worked out really well in my mind. I'd like to get some things across to them as happened in here [the "average" biology class]: about grouping, [that] it's useful, and [to give] the basic rules for it. But I know they're not going to stand for that vocabulary. This bunch didn't stand for it very well.

Aikenhead: Yet, they were very attentive.

Cheney: But my first [higher-ability] class just loved it. . . . So [for the lower-ability biology class] I think I'll have to adjust a little bit, expand the middle portion of the lesson so they really get the idea of grouping.

Aikenhead: Essentially the same lesson but modified, then.

Cheney: This bunch, they're quite special to me; but you obviously can't do the same things with the same outcomes as you can with the others. So we'll just have to play it by ear and see what happens. . . . I always judge this group by a finished product. Like, many of them when we started the projects never did anything for hours and hours and hours. And then when it came down to the crunch of handing things in, many of them were in overtime on their time, something that never happens in other classes. So they were slow starters, but if you don't give up on them it seems that there's going to be a

> product. So we're going to concentrate on product here, and maybe get them to know a little bit of biology.

And did Mr. Cheney change his plans in midstream? Dramatically! The notes copied during the first part of the lesson were completely different. "I've taken some of the information from chapter 14 and have summarized it for you," he told them. The students copied the notes, exhibiting the same concentration as the "higher-ability" students. The second part of the lesson – the introduction to classification – lasted 30 seconds compared with 6 to 10 minutes in the other classes. The students then were quickly pushed into the activity of describing how common things were classified and what criteria were used. Mr. Cheney moved around the room to help various students get started. The activity and answer-sharing would have taken just as long as the other classes took, except Mr. Cheney had added a few extra common things to the list (newspaper, school yearbook). Instead of tracing *Canis familiaris*, the students compared such trios as whale, fish and horse, or grasshopper, crayfish and lobster, in order to speculate on structural similarities. Then quickly their attention was drawn back to the overhead projector where Mr. Cheney went through a key that would distinguish among four common objects. The students, in pairs, were given the task of picking out four students in their class and devising a key that would distinguish among the four. The key was to work in the same manner as a biological key. Some of the students were prone to use such biological features as "virgin/nonvirgin" in addition to hairstyle and hair colour. The assignment took approximately 15 minutes and with it ended the period.

With these lower-ability students, Mr. Cheney changed his speech patterns. He spoke in a more staccato manner; each phrase came out like a mild verbal punch and there were seldom moments of uncertainty in his voice. However, the message content for the lower-ability students had a greater frequency of positive reinforcements. Mr. Cheney's disarming smile broke out with the same frequency as it did with other classes where his speech style was more reflective, tentative and rich with biological examples.

Teacher Beliefs

Later that same day I talked with Mr. Cheney about the three biology classes. The lower-ability course, he said, had been developed to respond to a need in the school. Two objectives of the course were to develop an appreciation of the environment, and to develop the knowledge and skills to interact with the environment. When asked to compare these objectives with those for the "average-" and "higher-ability" students, Mr. Cheney explained that for the lower-ability students the priority was the former objective, while for the other students it was the latter.

Cheney: They [the higher-ability students] can handle activities in more of an abstract way than the [lower-ability students] can. So you could still do the same kinds of methods with each group, but your outcomes are somewhat different. You can use somewhat the same style if you like. I've been trying it. It seems to work well. . . . If you have some well-defined boundaries and have them either fuddle their way through it or all of a sudden start to snowball and catch on, that's good. That's the way it should go.

Aikenhead: Those boundaries are better defined for the less able group?

Cheney: Yes, indeed. If we have to, we'll funnel them in a few times to get them thinking "there really is something there, if we just try and figure it out." But the problem with the less academic group is that they don't have the patience, and the frustration level is much higher.

Aikenhead: How do you benefit, from a teacher point of view, from changing that style in the way you described, from the more subtle to more explicit? How does that serve your purposes?

Cheney: Well, one of the things I told you this morning is that the lower academic group deals with product. If we concentrate more on product, it makes for all-round good feelings. I'm happy when they get something done. They're happy to get it done. They feel better about being able to do something. Whereas if you go into a situation where they just can't do it – and it's not a question of repetition and drilling or whatever – it's just not worth that kind of scene. Well, how can we come away with any kind of good feelings? At least here there are a number of things they're going to do. And some will do them extremely well. . . . The feeling is there, and yet [the work] is academic.

There were many practical reasons why teachers altered their instruction for different student abilities: reasons of survival; reasons of pride; and reasons relating to the wellbeing of the students. This wellbeing was most often rationalized in terms of socialization and preparation for academia. While I saw basically the same course taught to different students, teachers expressed the view that significant modifications had been made.

In Mr. Cheney's three biology classes described above, the students had similar assignments and similar lessons, although the emphasis and expectations were greatly different. Mr. Cheney seemed concerned that the work be perceived by colleagues and students alike as "academic." "Academic" was what the higher-ability students did. "Academic," understandably, related to what is done in, or in preparation for, university biology, where Mr. Cheney once taught for several years. Mr. Cheney was adamant that the academic content for the lower-ability students was not an illusion. He believed that these students could accomplish academic work. He had results to support his belief. Students did learn grouping strategies to some extent. They did learn to devise and use a key to some extent. They did show pride in their insect collection. In this sense, then, they did experience success in the academic work as Mr. Cheney conceived it. He felt happy. They felt happy. He hadn't altered his goals, just the priority of those goals. It appeared to me that he had conserved his belief in the value of academic work.

Similarly, Mr. Almon valued quantitative problem solving in physics very highly. Project Physics was too nonmathematical, he believed. He used a modified Physical Science Study Committee (PSSC) approach in his class.

For one grade 12 class I observed, he had carefully gone over how to do a kinematics problem and how to pick the appropriate equations to use. Five kinematics equations were printed on a cardboard sheet hung at the front of the room. In discussing this lesson with him, I asked him about quantitative problem solving as a focus for physics work:

Aikenhead: I guess it comes to the very general question, "What's the point of doing problems?"

Almon: The overall answer is to get through the problems in order to learn some problem-solving techniques that apply in a number of different places, from physics to science, and then to all of life. . . . Kinematics serves as a base for all the other mechanics in physics, so the material is important to future problem solving they do. On the whole, the material is probably secondary to the problem-solving techniques. But kinematics is vital.

Aikenhead: You mentioned before "use in life." What's the payoff in everyday life for this kind of problem solving?

Almon: Well, I think whenever you have any kind of problem in life, the person who writes down what the "givens" are in a situation and then systematically solves a problem usually, in my opinion, comes up with a better answer, a better solution compared to the person who just tries the hit-and-miss technique.

Aikenhead: Does that mean that by doing these kinematic physics problems, something is transferred to everyday situations?

Almon: I think there is. I don't say that by doing these problems today there is. But through the whole year we do an awful lot of problems of different sorts, but all have the same basic technique. I think there is a transfer. There was for me. I've learned to solve problems in life like I've learned to solve physics problems. I don't know when that took place, when it got into my head, but it surely did happen.

As the above discussion evolved, I probed the worth of learning quantitative problem-solving techniques. The ultimate justification for

Mr. Almon turned out to be the preparation of students for the next level of education. I suggested including in his physics class an everyday situation, like buying a car, but he did not find that idea attractive, perhaps because such an activity would detract from the quality of preparation for the next level of education. It just wasn't "good physics."

When we were discussing choosing the items that constitute an exam, Mr. Almon expressed the view that students who could not achieve on the "application" items could achieve on "comprehension" items – those problems practised in class and for homework. He believed that this lack of understanding the applications of physics was compensated for by the problem-solving techniques they learned from mastering the problems. Consequently, he felt that students who could do problems deserved to pass his physics course. When given the choice of either altering the curriculum content so that students could succeed at application questions (that is, on questions other than quantitative problem solving), or altering the exam content to include easier items of a quantitative nature, he chose the latter alternative. Mr. Almon's allegiance to problem solving was firm.

Mr. Dareichuk also stressed problem solving as part of his "theory of physics." On the first day, he introduced his class to physics by asking "What is physics?" He wrote down student responses on the blackboard, mysteriously categorizing them into two columns, and later labelling the two columns "theory" and "application." The students were told that they would be studying the theory and then the application of those topics written on the board. When I asked Mr. Dareichuk about the function of physics applications in his course, he remarked that this everyday aspect of physics was the course content that "reaches the students," especially the average-ability students. I pushed Mr. Dareichuk on this point: "What if you taught grade 11 physics to the average-ability students from the basis of application, and brought in theory only in spots?" Mr. Dareichuk said that the consequences would have been twofold. First of all, the teachers at Prairie High would have to change the grade 11 physics course, and this would conflict with teachers' preparation of students for postsecondary institutions that require the theory. Secondly, the theory tied everything neatly together, giving meaning to physical phenomena. This parsimony of meaning would be lost in a course taught on the basis of applications to everyday life. Not only did the theoretical nature of physics have pragmatic value for Mr. Dareichuk, it also had aesthetic value. He appeared to be guided by these beliefs in many of the curricular decisions he made.

Goals for Science Education

Much of the instruction in science classes at Prairie High, as we have seen, emphasizes the discipline's content (learning the correct explanation of natural phenomena) and obtaining a solid foundation for the next level of instruction (preparing for university, technical institutes or the next grade level). However, I also observed instances where teachers emphasized certain characteristics about the nature of the scientific enterprise itself. I must warn readers that the teachers generally associated me with this particular emphasis. We discussed the possibility that my being there might encourage them to teach more about the nature of science than usual. The following data comes from those instances where the teacher and I both believed that the data represent typical science classes.

I was present for most of the September introductory classes in science. The question "Why do we study science?" was posed to students in more than one classroom. The answers given in Mr. Epp's class were typical: "To understand the true meaning of things around us"; "To learn the facts." These responses reflected a view of science as the accumulation of facts in order to know the truth about nature. In Mr. Bews' class, the question "Why do we study science?" was rephrased after a student laughingly said, "Because I have to." When Mr. Bews asked, "Why does society insist that you study science?" more socially pragmatic answers emerged.

Views of science can be communicated explicity to students by the messages they hear or read in the classroom. Although all teachers at Prairie High communicated implicit messages about science, several talked explicitly about the nature of science. These teachers' classroom events constitute the major source of data for this section of the case study.

In a grade 11 "average-ability" biology class, Mr. Cheney was discussing criteria used for classifying, and had elicited from students criteria for the biological groups "animals" and "plants." He said to the class:

> "On the cover of your textbook there's a very interesting living thing that uses light to produce food. Yet it's a real problem in classifying. Do you classify it as a plant or animal? Obviously our neat little categories are somewhat disrupted. But still useful for the most part."

This emphasis on scientific knowledge being useful as opposed to being truthful, repeated itself in many forms and on many occasions in Mr. Cheney's classes. For example, in reinforcing a student's rationale for learning the biological classification system ("You could put things in order"), Mr. Cheney wrote on the board in large letters, "VERY USEFUL." In a grade 10 class discussing the experimental findings of a solubility lab that used graphic techniques, Mr. Cheney said, "So a graph can give you a whole lot of useful information and, whenever possible, we in science try to show our results in graphs. It's a picture, and it is useful mathematically."

I spoke with Mr. Cheney about the way he used the object depicted on the textbook cover with the higher-ability classes:

Aikenhead: One student said, "What is it, really?" They were saying, "What is the truth?" And you said, "You can't classify it!" and left it at that.

Cheney: They don't like that [laughter]. Some of the ones who aren't prepared to do some thinking about it don't like that. Some of the ones that are prepared to do some thinking on it will be quiet about it and come back to you later, or when you come back to them they'll have at least thought about it. And some of the ones don't get the point of any of it. Now when I threw out that same thing to my [higher-ability group], not one of them asked that question.

Aikenhead: What does that communicate to kids about the nature of science?

Cheney: Well, and I always try to get that point across, that science doesn't know everything. I guess that's true of the general public, they just have more faith in science's ability than people right on the frontiers have.

The nature of science became an explicit topic in Mr. Dareichuk's higher-ability grade 9 class, where students read about observations, direct and indirect evidence, experimental design, dependent and independent variables, conclusions, hypotheses, generalizations and models. Small groups of students discussed these ideas among themselves for several days and then wrote a test. Mr. Dareichuk was disappointed with the results. He carefully went over the topics listed above when he took up the test in class. In a discussion about the nature of scientific models, he encouraged the students to draw upon their own ideas about models. From their ideas, he developed the idea of a scientific model. Many of the student responses on the test had not been specific enough to meet Mr. Dareichuk's standards of a "good answer." The following discussion shows how Mr. Dareichuk provided his students with the standard of answer he expected of them:

Dareichuk: What is a model?

Student: A construction or reconstruction of [inaudible].

Dareichuk: A reconstruction. O.K., that's a little bit nebulous. I'd like you to answer a little clearer than that.

Student: A mental picture.

Dareichuk: A mental picture. Judy said that. O.K., and now if we want to. . . . How can we record that a little bit more, when we say a mental picture?

Student: A model is something which looks like the real thing but is smaller or larger.

Dareichuk: O.K. Now, how are you forming that model? How do you know when that model is like the other real thing. What do you mean by "one being like the other"?

Student: [inaudible]

Dareichuk: O.K., by observations. . . . How do you form this mental picture?

Student: An educated drawing or picture of something. . . [inaudible].

Dareichuk: What do you mean? What is an educated drawing or a picture?

Student: You have some education. . . .

Dareichuk: But, uh, what is, when you say you're making an educated guess, what is this so-called educated guess as opposed to an uneducated guess?

Student: You know something about it.

Dareichuk: All right. You know something about it. . . . What is your understanding of an atom? What are some ideas you might have?

Student: All things are made up of atoms.

Dareichuk: All things are made up of atoms. O.K., now what are atoms?

Student: They all have small [inaudible].

Dareichuk: So they are very small. You're saying small particles then, right? I noticed you said neutrons and protons. So there's another statement that gives us two different ideas. They're made up of small particles. You mentioned at least two different kinds. Anything else?

Student: The electrons circling around.

Dareichuk: The electrons circling around. O.K., so there's another particle we've mentioned. We're getting a bigger picture here then. And you say now circling, eh? All right the ideas I'm after when you say a mental picture, a mental picture is formed by what, then?

Student: [inaudible]

Dareichuk: Right. Information or a series of ideas. So we need lots of ideas to try to formulate any kind of model. And so with the model here, most of you were familiar with building models of different types, and you're saying a model is usually a replica of a smaller size or a larger size, but I wanted you to realize that this didn't have to be concrete, or three-dimensional. It could be series of ideas that you need to put together to make this thing.

In Mr. Bews' grade 11 higher-ability chemistry class, I noticed that he enunciated ideas about the nature of science with unusually high frequency. The class had collected data that, when graphed, suggested a relationship between gas pressure and volume. For Mr. Bews, the lab served the purpose of getting students "back into the groove" of quantitative work. In our discussion before the class, he indicated that, while the lab write-up was a mathematical exercise, he wanted students to think about the relationship between the mathematics and the behaviour of nature. However, he recognized that students would likely be satisfied with just the mathematical aspect of the write-up. The verbal interaction between Mr. Bews and his students contains several messages about the nature of science:

Bews: All right, well then, let's infer a relationship between gas volume and gas pressure, for a given sample. Are there any other qualifications you'd like to make? [pause, no student response]. Something you didn't worry about, but it is something probably in the back of your mind [pause, no student response]. You did this lab with a fixed sample of air and at a fixed. . . [pause]. It starts with "T."

Student: Temperature?

Bews: Temperature! [Looking at the straight line plot on the board of P versus 1/V] What would you do if you were to extend that line? What would that mean? You have no data down here [blank region of the graph]. What right have you to extend your line? You're assuming something. What are you assuming?

Student: [Says something about the rest of the points following the average.]

Bews: Are you absolutely sure that would happen?

Student: Fairly sure.

Bews: Absolutely sure?. . . . You are making an assumption and you must recognize that. When you extrapolate that line beyond where you have data, are you not assuming [inaudible]. And on that basis? Careful, this is very, very, very meaningful; this intercept [points to the intercept of the line with the z-axis]. Besides doing it, make sure when you find that intercept that it is very, very, very, very meaningful, not just an intercept. . . . Then you plot 1/V against P. What did you get, Lisa?

Lisa: I got a straight line.

Bews: Did you really?

Lisa: Uh huh.

Bews: Perfect?

Lisa: No.

Bews: Not perfect. Why not? O.K., are you perfect?

Lisa: No.

Bews: Is the apparatus perfect?

Lisa: No.

Bews: Am I perfect?

Students: [laughter]

Student: Is it just error that we didn't get a straight line? [referring to her results, for which only one data point out of five wandered from a straight line].

Bews: Well, let's just take that.

Student: Mine is wrong.

Bews: Yours is wrong? Maybe theirs is wrong!. . . You don't think you have the right answer until you collect a great magnitude of data. But that would take a long time [laughter]. Most people think it's a straight line. The guide says it's supposed to be a straight line. O.K.?

Student: It has to be a straight line.

Bews: A straight line through most of your points. I think you'll probably find that is reasonable.

During the discussion afterwards, I suggested to Mr. Bews that he had, in his teaching, raised issues about assumptions, qualifications, meaning, accuracy and authority:

Aikenhead: Is this a style that characterizes your teaching? You take time out in class to do this?

Bews: Most of that is deliberate. I don't think it is accidental. And some of it, perhaps, does come through accidentally without forethought specifically. But those things I believe!

Aikenhead: There's a time to discover and there's a time to [inaudible]. Are there some other statements that I would write down that just didn't come up — other beliefs about science?

Bews: Well, I think that it pays off to be tentative. I think that's true. I think if that doesn't come through then something is missed.

Aikenhead: That's the observation that one gets from an experiment. One should be tentative.

Bews: Sure, and [inaudible] be larger than that, too. One should be tentative about issues, as well as data that you generate in a class situation. It pays to be tentative, to be reserved about gung-ho things, about what's right and what's wrong, particularly scientific things. Morals play a part, too. Not in Boyle's law. That's pretty difficult, to bring morals into Boyle's law, but there are issues in science which are not clear-cut.

Similarly, in September Mr. Epp emphatically stated that science is a verb. "We're here to science," he told his students. He defined this as observing carefully, forming conclusions and communicating to others. Mr. Epp was one of the few teachers who consistently mentioned the names of scientists. While he talked about doing science, he expected students to use their computers (his metaphor for brains) to store a library of precise facts. This expectation was particularly evident when he discussed the decline of academic standards and student grades, an issue considered later in the case study. The precision of knowing specific facts and explanations was not only a characteristic of his testing, it was also evident in his classroom teaching:

Epp: The particles are moving faster; then they're moving further apart. If the particles are further apart, what do we know then?

Students: [many inaudible responses]

Epp: What becomes less?

Student: [inaudible]
Epp: No!
Student: Things will become [inaudible].
Epp: No! [pause] That's true! Yes! Pardon me.
Student: The attraction becomes less.
Epp: Exactly!
Student: You got it.
Epp: Don't give me a grade 9 answer: "The space is larger." Where? Which one?
Student 5: The space between the molecules of water are larger so liquids have larger spaces than solids.
Epp: Good.
Student 5: We're learning something, Mr. E.
Epp: Right. You guys are really going to get there someday.
Student 6: [Asks a question about the upcoming test.]
Epp: You've got it up here in the computer [points to his head]. Total recall. The other kind of question I ask you is what happens, when? [pause] What happens when I put cobalt chloride in water? For three marks, three things happen. What's one?
Student 1: It dissolves.
Epp: A grade 9 answer! You're in grade 10.
Student 2: The water turns a different colour.
Epp: That's one, but that isn't good enough, is it?
Student 3: No.
Student 2: O.K., it's, uh. . . .
Epp: Not for you guys, you're sharp.
Student 2: The colour.
Epp: What colour?
Student 2: The colour of the liquids inside changes.
Epp: No, no, no, no!
Students: [Simultaneously] They blend. They mix. They combine.
Epp: What colour!?
Students: Red. Scarlet.
Epp: Right! Or burgundy or crimson.

Mr. Almon expressed a highly empirical view of science when we discussed what students gain from doing experiments.

Aikenhead: To what extent were the series of labs an inquiry?
Almon: It was an inquiry in that they controlled their own experiment, although many used models from before — the tables and things — and that was fine, but they had to apply what they learned previously to a new situation. It seemed to be just the right amount of new thoughts that were required. They were able to make that transition quite well and they learned a lot by making the transition from one experiment to the next. But those were very similar experiments. They didn't know the answer. Some predicted wrongly in their hypothesis,

still. And some even wrote down the wrong conclusions looking at the results because they wanted to make their hypothesis true, which I pointed out to them.

Aikenhead: But isn't that what scientists do?

Almon: [Laughter, more nervous than jovial]

Aikenhead: Isn't that how the Millikan electron drop experiment was?

Almon: I guess the first time it was.

Aikenhead: You want them to be logical and stick with their data.

Almon: Oh yes, if they can't believe their data they should do enough additional examples so that they can prove it to themselves.

Aikenhead: But the fact is that some big scientists don't do that.

Almon: Well, it's only through bad training. In the long run, it's a real danger. There are scientists who do that today and come up with wrong conclusions. In general, you have to stay away from that, that good results do not outweigh the bad. There's been so many bad ones. You run into it in terms of testing for safety of products. So many of those tests can be falsified, and the public suffers for it, not just science.

Mr. Almon did not seem to provide his students with experiences that illustrated the complexities of scientific inquiry. Instead, the lab experiences suggested an idealistic view of scientific inquiry, one in which data controlled conclusions in a strictly logical fashion.

Apart from deciding what to convey about the value of science, teachers also felt that the emphasis on teaching the nature of science topics took time away from the content of the discipline and compromised the efficient use of students' time. This idea emerged when Mr. Dareichuk and I were talking about alternate ways his students might carry out the lab on refraction; inquiry had been mentioned:

Aikenhead: When you get some hypothesis, and then you can predict what should happen. . . . But that takes a long time, for people to play around.

Dareichuk: Yes, and try to experience. I've thought about the idea, but it's trying to work it in somehow, and get them to work more, so eventually they become more efficient that way. But I just haven't been able to resolve for myself a way to try to get them to carry through on that, day by day, until finally I covered the year to make it work that way. I think I'd have to experience the situation under somebody that does have it working.

Aikenhead: Covering the syllabus, that's pretty difficult to do.

Dareichuk: That's what I feel, too. Because [the students] need so much more time, to begin with, to try to get their ideas sorted out, to find out which way they're going to go. And, in my mind, I think, too, you can make use of your time much more efficiently. They can get their ideas out of it if you still keep them thinking and trying to arrive at conclusions, and so on.

I know they're losing this idea of that inductive approach, but what we're saying is, it's much more inefficient. And we don't have that much room for that particular approach in our courses.

Technology

The relationship between scientific content and its technological application was mentioned by all of the teachers when they discussed their teaching, but in the classroom, technology was seldom emphasized. Mr. Dareichuk believed that too much technology content could detract from the quality of his physics course. Nevertheless, technological applications did surface from time to time in his class. Across the hall, Mr. Cheney cited instances where science and technology interacted; for example, the effect of the microscope on altering classification schemes. Mr. Cheney also coloured his lectures with numerous environmental applications. These technological examples would seem to move students closer to his espoused teaching goal — appreciating the environment.

Mr. Almon clarified his view of technology content in the classroom during one of our discussions. He had finished justifying the use of hand calculators in his physics class by pointing out their uses in everyday life. I wondered if this everyday justification would also apply to the technological world of his students:

Aikenhead: Would the same argument apply to, for example, starting a unit in optics with technological things like cameras, microscopes and lasers, and learning some of the technology and drawing upon the science content in order to teach some science?

Almon: Yes. Definitely. It's a very difficult thing to do because of the material that you'd need. I try and do that, if at all possible. For instance, we were talking about refraction and critical angles and things like that. So we were able to talk about fibre optics, and I purchased a five-dollar fibre optics lamp [that] showed critical angles. To me fibre optics is a very important thing for kids to learn about right now.

Aikenhead: When you take the time in class to work with fibre optics, it does take away time for studying physics.

Almon: It certainly does.

Aikenhead: Some people would argue that it's also much less rigorous than problem solving. I'd like your reaction to the same argument we used about calculators, bringing in these technological examples.

Almon: Well, I think it makes [the students] much more able to relate to the problems once they see them as relating to real life. If I did a whole series of problems on critical angle, and a student had never seen what a critical angle actually means. . . they're doing a bunch of abstract things that mean nothing to them.

Aikenhead: So you see the advantages of those demonstrations outweighing the time taken to do them?

Almon: Yes.

Aikenhead: That must be a difficult decision for a teacher to make — how much time to take out of a class to do things which have this motivational aspect.

Almon: Yes.

Aikenhead: And when do you stop motivation and say "O.K., it's time for physics"?

Almon: I would do motivational things all the time if I had the materials, and I would give them the math to do at home. I don't have the materials, or the knowledge to do those motivational things. Those are the things they remember when those kids come back two or five years later to ask for help on university physics and problems. They remember the demonstrations. They even remember the concepts behind them. They don't remember any equations.

Aikenhead: That makes you feel like you've accomplished something.

Almon: Yes, and I also like to have an atmosphere in the class with a little bit of enthusiasm and excitement about science.

Mr. Almon thought that technology had value as a motivational device, and as a way of relating physics to the phenomena of everyday events. The phenomena, however, were generally restricted to the course syllabus; for example, rainbows, sundogs, mirages, telescopes and microscopes were discussed in class as phenomena related to refraction. I noted a subtle difference between Mr. Almon's view of technology – concrete demonstrations of abstract principles – and a broader view of technology – that which students experience in everyday life. Mr. Almon found the latter view of technology to be too complex; if he subscribed to it, he would run the risk of detracting from the science of physics. The motivational value of simple technological demonstrations encouraged Mr. Almon to use them as much as they were available to him. But where did he draw the line so that the time required for motivational material did not cut into the time required to cover the subject matter material?

Almon: Well, I guess that depends on whether the motivational things include much science, and whether those motivational things can make up for themselves in terms of students being more willing to put in more effort. In many of my classes I won't claim that the kids use the full class time effectively, right now. But it seems that the more motivation you can give them, the more effectively they are going to use class time.

And in many cases they are much more willing to do homework if they are motivated in your class.

Aikenhead: So, not trying to squeeze that extra four minutes out of them has a lot of payoff in terms of the work they'll do at home for you.

Almon: Yes. And it's not necessarily going to take away from the physics. Because if they understand the application, they may be able to think through a problem much faster. . . . You know, I'm really sorry that when I went through university I didn't pick up very many of the everyday applications, in order to understand the physics. When I look back, that was lacking. I don't know if it was the fault of the teaching or my fault. Maybe I was preoccupied with the mathematics. I was able to do very well in physics because of the mathematics. But I don't understand physics [the everyday aspect] as well as I would like to.

Science and Society

Mr. Bews brought up the science and social issues topic as we explored the ways in which he felt students should learn the value of being tentative:

Aikenhead: In what sense were you thinking that students should learn to be tentative about ethical statements?

Bews: I don't think that sort of thing creeps in very often in most of the work I do. Maybe I haven't thought that much about it. Or maybe I'm not competent. I'm not sure. It is something I would treat usually only in passing. It concerns me, and I don't really have the answers, and I wonder if the answers are out there.

Treating topics in passing was also a characteristic of Mr. Epp's teaching. He drew upon T.V. commercials as content to analyze in a scientific manner. When introducing students to "heterogenous" and "homogenous" substances, he discussed how dairies homogenize milk. In the midst of a classroom discussion over what names of elements students would have to memorize, in particular *kalium* (potassium), Mr. Epp mentioned potash mining in Saskatchewan, and the special process carried out there at the town of Kalium. A few days later we discussed this class and the function of digressions. Mr. Epp believed the curriculum did not include science and society topics:

Aikenhead: What are you trying to accomplish with that group with those digressions; for instance, potash mining and homogenized milk?

Epp: It's trying to keep these people's interest alive. If a person asks you a question and you say, "Well, that's not part of the course," you deflate him right away. I don't want to do that. I want to get them so they're asking questions and becoming interested in what's going on. I welcome a digression because it gives a student a chance to say something.

Aikenhead: The digressions are a way of allowing you, then, to cover those points.

Epp: Yes. The other thing is that [the students] have to learn a lot more than just the three R's at school. . . . That's a dangerous responsibility to put on a teacher because you can sway a student, I suppose. They become interested in what you're doing. . . . Where do you sit in a situation like that? These are results of many digressions.

However, with less able students, Mr. Epp worked to keep them on task and, consequently, discussion of science-and-society topics rarely occurred.

In a staff meeting, Mr. Epp alluded to students' ignorance of a uranium refinery controversy that had taken place a couple of years ago at Warman, Saskatchewan. I asked him if the uranium refinery issue ought to be a part of the science curriculum:

Aikenhead: What is your general reaction to spending class time, let's say grade 10, dealing with that kind of subject matter?

Epp: It's absolutely essential that we have that. Because after 19 days of the Warman refinery discussions, I found so much ignorance about the nuclear world that I was determined that some of these grade 10 kids I have will discuss *both* sides of it.

Aikenhead: What would you actually teach them in terms of scientific content?

Epp: Well, for example, people are concerned about yellow cake. One lady expressed concern that yellow cake was transported through Warman. She said, "What if one of them upset, would my husband become neutered?". . . You have more radiation from your watch. But this is the fear they have. When I listened to those guys at Warman I said to myself, "These people have graduated from high school, or are university students, and yet they really don't understand what the issues are." And I'd like these students to graduate from grade 10, or from high school here, with some knowledge, general knowledge, of what [the energy crisis with all its complex ramifications] is all about. And sooner or later they're going to be faced with a decision on whether they are in favour or not in favour of nuclear energy. Well, people are going to be faced with these issues. . . . So you have to have some background, and so then you come to deciding on a nuclear issue. . . . A person will say "I remember this about it, and this about it," and they have to make up their own minds based on both sides.

With the exception of Mr. Epp, most teachers did not find enough academic value in science-and-society topics to warrant their systematic inclusion in the classroom. However, the teachers certainly discussed such issues with students informally and outside of class hours. On several occasions, creation-evolution seminars spontaneously occurred in the biology lab after school. Students typically found all of the teachers most approachable. The teachers appeared eager to engage students in discussions that were beyond the scope of the curriculum, but not during class time, unless the teacher felt such discussions had potential for motivation or for clarifying the subject area.

Maintaining Interest and Assessing Learning

When it came to teaching, Prairie High teachers made it clear that science, society and technology issues posed problems for them. Mr. Bews was asked how he would assess students' understanding of science-society issues:

Bews: When I can say all those things, and give an exam or a test, I don't ask those things at all. I don't think I do. It's not deliberate. I don't sit and think "What am I going to ask them to respond to that would check whether they think this way?" I pretty well go right for the quantitative stuff.

Aikenhead: You feel strongly about that.

Bews: Yes.

Aikenhead: What is it, do you think, that keeps this [science-society issues] from being content on the test?

Bews: Maybe it's not just a way I would hope that students felt. If it's a way that they feel, I don't really care, frankly, if they ever act about that. Maybe also it's a question of trying to judge what they say, which is very subjective. My preference is for judging the quantitative things, quite frankly. I think I can be honest about that in keeping my point of view separate. I don't know. I haven't given that a lot of thought, quite frankly.

Aikenhead: Then it seems to me the big issue is that what happens in the classroom equals what's on the test. . . .

Bews: Yes. I spend a lot of time emphasizing. I spend most of my time emphasizing the quantitative nature of work they do.

And what was Mr. Bews's perspective on nature-of-science questions that were not objectively quantitative, but instead were more subjectively qualitative?

Bews: I shouldn't cop out, if it is subjective. There are teachers in other areas, and institutions, whose lessons are all subjective, and they learn how to handle that very nicely. I suppose it's my problem. I just haven't gained the confidence that I need, perhaps, or maybe it's that I'm not gutsy enough to do it. Period!

Aikenhead: But what is the difficulty in [marking subjectively]?

Bews: Probably nothing, quite frankly. If I got off my butt and did it.

Aikenhead: You'd have to feel quite strongly about that area of knowledge?

Bews: Yes I think I do, but I don't. I'm being inconsistent here, I suspect. I do feel strongly about it, yet don't pursue it with any significance at all in my testing.

Aikenhead: There must be good reasons for this inconsistency, though.

Bews: Maybe it's just easier to do it the other way.

While it was easier, it also conformed with the ethos of rigour, expressed through quantitative problem solving, so strongly prevalent in the beliefs of most teachers at Prairie High.

Objectively scored multiple-choice tests were used by Mr. Dareichuk because his marking was often done in the evening, and economizing on time was important to him. If he allowed students to justify their choice of an answer, he had to spend much more time marking their tests. Mr. Dareichuk's experience showed that only the "brighter" students took advantage of justifying answers.

Dareichuk: Yes. I have used that idea [writing a justification for a choice], and it works not badly for the brighter ones. The weaker students, of course, shouldn't be in this class. They generally don't use that advantage. They'll just pick out the multiple choice and stop at that point anyway. But some of the brighter ones do take advantage of this to express themselves. So, it might be a wise way to try out. . . . And partly my choice too, is, when you're trying to mark in the evenings, and if you allow too much extra variation like that, your time element is too big a factor.

Aikenhead: Yes. It would cut down on the amount of questions you could ask.

Dareichuk: Yes. If you can get your questions a little bit more objective, then you can mark faster than you can with a more subjective type.

A somewhat different viewpoint was expressed by Mr. Almon, who gave part marks to students showing the correct reasoning, although their final answer may have been in error:

Aikenhead: Is that something that you evolved yourself, or is it something that happened to you and you like it?

Almon: Well. Maybe it didn't happen to me and I didn't like it. It's easy in physics to make a ridiculous math error. . . . I don't do multiple choice anymore. I started out using multiple choice quite a bit, because it was easy to mark. . . but the validity of the testing just didn't seem to be there. Bright kids could mess up the test just because it was multiple choice. Students feel better about their marks.

In his higher-ability classes, Mr. Epp had included a number of science-society digressions. But, from his perspective, the digressions were not legitimately testable, because he had included them for interest's sake only. (Mr. Almon and Mr. Dareichuk included technological content in their lessons for the same reason.)

Aikenhead: When you set the exams, then, you have in mind the material they've covered in class that they should be able to remember.

Epp: Yes.

Aikenhead: Now, as far as the digressions are concerned, that's also very important for the students who can handle that, the brighter students. Do you have that content on the exams?

Epp: No, I don't. Digressions, no; because it's primarily of interest to one student. Now the other students maybe, but they may not be interested. . . . You'll find in this class (grade 10 "bright" students), these guys are all struggling for marks – the most important thing they can get. I don't know, we've got a mark-happy society. . . . If I put a digression in [a test item], I'd have to have written it on the board [for their notes] and explain the whole thing. Maybe that would be something to think about.

Of course, tests were not the only form of evaluation. Mr. Cheney mentioned how he evaluated students in the "subjective" realm of the nature of science.

Aikenhead: This [the nature of science] is a pretty important idea to you, obviously, because you've spent time on it in class. Does this kind of learning show up on your evaluation of students?

Cheney: It does in a number of ways. One of the ways most teachers use is they have a "fudge pot." The only thing the parent is interested in is the mark. And yet most of the students know that there is a hell of a lot more to school than just that mark. But they're prepared to play the game. And so by having the "fudge pot," things like 47s can be turned into 50s; things like 57s can be turned into 60s. Whereas three marks aren't very important to me, it might be very important to the parent. . . . So I use the "fudge pot" to paint on the proper thing for the parents.

Mr. Cheney went on to describe that this type of learning by students was not expressed in written form, but by how students carried out labs and projects. He felt confident that when he and the student interacted one on one, he could assess their inclination to do some inquiry and to do some thinking in science.

Testing served different purposes for different teachers at different times. I asked the teachers what role testing played for them. Mr. Epp felt that testing set standards for students, and showed areas where students were having problems. Mr. Epp's standards demanded that students remember *specific* information:

Aikenhead: It seems to me, as an outsider coming into your class, you value a kind of learning that makes students interested in science. You said that to me the very first day. Students' interest in science is a good goal.

Epp: Yes.

Aikenhead: But on the other hand you're saddled with a curriculum guide; it has specific information. Now, when it comes to evaluating and standards, you seem to have chosen the curriculum guide content. But something more important to you fundamentally is the knowledge that relates to the interest in science. And so the thing I find confusing in my mind [is that] when you talk about standards, you relate standards to something you feel saddled with, rather than to something you value highly.

Epp: I try to use both. It's very difficult. I'm not pleased with this course. . . . Students were more interested in the other course. But they're developing an interest now.

Aikenhead: How would you relate giving them credit for tangibly expressed interest [in the course]. Is that "low standards"?

Epp: Well, no. It is all part of the evaluation process. One thing that is important to me is response in class. When I ask a question I get the same four hands up in every period. That is disconcerting. I'd like to see different people. I don't think you can evaluate that, but you do keep that in mind when discussing with parents.

Mr. Epp, like most of the science teachers, distinguished between classroom events for motivation purposes and classroom events for evaluation purposes. If scientific inquiry or science-and-society topics were introduced primarily for their motivational value (from the teacher's point of view), this content was not evaluated. Students had to learn which classroom events would be tested and which wouldn't. The first test of the year provided students with grounds for making this distinction.

The first test of the year in Mr. Almon's physics class turned out to be unusual, but it served the purpose of motivating students.

Aikenhead: You mentioned to [the students] that this is the first test and it won't be hard. . . . What's behind your decision to make that kind of test?

Almon: Why start with an easy test? I guess it results from other years. . . . It is also an idea that kids are a little bit afraid of physics, even top-level kids, and they really are if they fail the first time. . . . If they do poorly they're going to hate physics for the rest of the year. It's even more important with a lower-stream class — you get some guys who are really interested in physics, and then if they fail it the first time, they're [going to say], "This is just going to be a credit, maybe, if we're lucky, and I'll plug through it, but I won't enjoy it."

Many of Mr. Almon's classroom events — interacting with students, and so on — appeared to address the basic issue of motivating students. Mr. Dareichuk used a similar tactic to arrive at an acceptable balance among student achievement, student effort and student self-motivation:

Dareichuk: I want them to sharpen up. . . . Some of them are very good, others are very low in their effort.

Aikenhead: Does this affect the way you design your tests?

Dareichuk: It does. . . . It's just very simple, almost very similar to what they've done in class, otherwise it really bothers them.

For many of the teachers, the idea of working hard always came up in discussions about testing. Mr. Almon returned to this topic, and others, during a subsequent discussion about teachers having full control over what items they put on the test and therefore having full control over the marks students receive. Mr. Almon saw it as his responsibility to challenge every student on his tests. But it was also his responsibility to make sure the mark distribution did not discourage students. He achieved a balanced student achievement by the way he set his tests, by his attempts to motivate students in the classroom by rewarding effort, and by expecting his students to push themselves in their studies. Moreover, the value of a challenging test reflected Mr. Almon's belief that the best secondary school science is that which approaches, in both content and methodology, science as it is taught at university. However, this ideal had to be compromised occasionally (by asking students to complete easy comprehension questions, for example) in order to motivate students by ensuring their achievement. Thus testing presented Mr. Almon with a dilemma. For Mr. Almon, resolution of the dilemma involved a number of interacting trade-offs and counterbalances:

Almon: Ideally, I would like to see a lot of kids with A's.

Aikenhead: But you set the exam. You determine that.

Almon: I want to have it so it evaluates everybody. So everybody is evaluated in how they are doing. I still get a kid who gets 100 per cent on an exam. I don't want to have an exam that, for some, isn't challenging. Everybody I want to be challenged. So it spreads them out. If I could teach well enough, I should have all A's.

Aikenhead: You feel that all students are intellectually capable of getting there?

Almon: The abilities are there, if they could be tapped.

Aikenhead: When you say "tapped," you mean motivated?

Almon: Yes, motivated well enough.

Aikenhead: What would they have to do, once they are motivated, to get A's?

Almon: To work through enough problems so that they could figure out the steps involved in a problem. To be motivated to push themselves to make the abstractions. Some students seem almost too lazy to do the kind of thinking required to solve a complex problem. Some others just haven't had the experience of problem solving. Experience really helps. If they really are too lazy to do the thinking, they are never going to make the progress through the further steps. If they were motivated to take the time to push themselves, then they would make that jump to a higher level of thinking. But they aren't. I haven't been able to motivate all the students.

Mr. Dareichuk had used testing in a different manner with his grade 9 higher achievers. Their first test of the year had given him feedback concerning the efficacy of a teaching methodology he had just tried out. He was disappointed in his students' achievement, so he decided to alter his instructional methods for the next unit of work. He shifted from a "small group discussion" approach to a much more "structured approach with the whole group moving together." On the next test the students did much better. I was present in Mr. Dareichuk's class when he went over the first test. Afterwards, we analyzed the test. There was a multiple-choice section (taken from the textbook's teacher's guide) and a short-answer section. I expressed surprise at the difficulty of the subject matter; for example, students were asked to select dependent and independent variables from a description of an experiment. I mentioned that my second-year university students were having difficulty picking up the concept of variables, let alone dependent and independent variables.

From Mr. Dareichuk's perspective, the results of the test were valid because, he said, he had taken it from the teacher's guide. Therefore, if students did not do well, it was due to inappropriate instruction, insufficient effort on the part of the students, or inappropriate placement of students in a higher-ability class.

A postscript: Mr. Dareichuk decided to give the students "a break" to help them get over their low marks on the first exam. He was delighted by their response to his suggestion of not necessarily counting the first test. What was their response? They dug into their science work with a fervour rarely seen all year. It would appear to be an artful, almost intuitive, decision of when to swing the balance towards "strict standards" and possible low achievement, and "softened standards" with a resulting high motivation. However, perhaps the phrase "softened standards" is a misnomer for the realistic perception of the problems inherent in testing and evaluation.

Somewhere and somehow, teachers developed these views about evaluation. Several teachers mentioned that their experiences as high school and university students probably served as personal events upon which their beliefs were formed. For example, speaking of the stress placed by teachers on quantitative problem solving, Mr. Bews had this to say:

Aikenhead: This view of the quantitative and how it is helpful. Is it possible to pinpoint or even describe where you developed this value yourself?

Bews: I don't know the right answer, but I suspect that a good portion of it came from [premedical training]. Science was particularly quantitative from morning to night. Literally, I can't say I revelled in it. But I came to see how quantitative things could be, and the kinds of skills you had to have or develop if you wanted to be reasonably successful. And since I was relatively successful, I suppose I still think they are good values.

Aikenhead: Right.

Bews: Because I struggled at [quantitative work at university], I think I was better from the process, because I had to struggle. And I know what some of those people out there are going through.

Mr. Almon, on the other hand, was sorry he had not seen his physics work in a different light at university:

Almon: You know, I'm really sorry that when I went through university I didn't pick up very many of the everyday applications, in order to understand the physics. When I look back, that was lacking. I don't know if it was the fault of the teaching or my fault. Maybe I was preoccupied with the mathematics. But I don't understand physics [the everyday aspect] as well as I would like to.

Experiences at colleges of education were also mentioned. Teachers talked about individual instructors who had made a very positive contribution to their experiences of teacher education, or who had been ineffectual because of their isolation from the real world of teaching. Professors at colleges of education who had isolated their course content from the "infection" of classroom realities were perceived as offering sterile courses; idealism and theoretical constructs were most often cited as the antiseptics. Only one-half of the Prairie High science teachers had actually taken a science methods course at a college of education. The others had had their science training at the College of Arts and Science.

The following discussion with Mr. Almon illustrates how these teachers viewed their teacher training:

Aikenhead: We've been talking about testing and choosing what should be in the curriculum. Where do you see these ideas coming from for you? From your science classes at university? From the college of education classes? From your experiences? Where do some of these ideas come from?

Almon: The majority of the ideas come from my own experience as a student, from what worked on me. Very few of my ideas, that we've talked about, would come from the college of education. . . . But my original ideas would come from high school and university physics classes, and other classes in related fields.

Our discussion turned away from the college of education and went on to explore inservice teacher education:

Aikenhead: Talking about changing in a classroom, the changes that you're talking about are changes in how to achieve those goals. You're not dealing with changing those goals?

Almon: Well, I would certainly be open to changing those goals, but I would have to go to a situation where I could see the benefits of changing my goals. I like my goals right now, but just as science changes, my goals could change as well. Like, I have known [physics] teachers who stay away from the math a great deal; you know, try and teach only the physics without any math. And they've told me they've been very successful. Now if I could go and work with them a while and see what happens to the students, you know, even watch what happens when they go to university or go on to everyday life. . . . Quite possibly my goals would change.

Aikenhead: When you're talking about arguments, you're talking about personal experience.

Almon: That's the way I learn. I don't learn very well by theories or arguments. If I could actually see the results, then I'm sure I could change. . . . My goals are based on what I've seen over the years, and so the only way I'm going to change is, you know, if somebody would give me a different set of experiences to make me see their point of view.

The Student, The Subject and The Work of Teachers

Tests in science classes at Prairie High seemed to emphasize objectively scorable, singularly precise answers. If testing alone taught students something about the nature of science, it was that science is a rhetoric of conclusions. Classroom content that strayed into the divergent, qualitative and somewhat subjective realm was not seen to be amenable to testing. However, such content was generally perceived as important for motivating students and, in some cases, for evaluating them in ways other than by testing.

What was important to know about science seemed to be related to what students could learn from science. Habits of orderliness learned from an orderly subject were important. Getting the interest of the student was more important than forcing compliance through sanctions. Take the case, for example, of the grade 9 students and the low-ability students. These students were often the objects of attention whenever the topic of student socialization came up. Ninth graders were seen as needing self-discipline, especially in study skills, and teachers assumed the responsibility for taking appropriate action. When discussing grade 9 students, Mr. Ford indicated that he would not hesitate to detain a student after school for not handing in an assignment. It was important to the teacher that students got the message that they must do whatever the teacher feels is worth doing. When students did work well, then the teachers could view classroom events in terms of serving other curricular ends. I explored this idea in greater depth with Mr. Almon in discussing how students were to do their lab reports:

Almon: They have to learn that when I say it is to be handed in the next period, that's what I mean; and I'll mark it.

Aikenhead: Why's that important?

Almon: Because they have to learn the responsibility in terms of, you know, when they're told they must hand it in, that doesn't mean that they can come the next day and say "Well, can I have another day, I didn't have time."

Aikenhead: What would be the consequences if you were to allow something like that?

Almon: Well, then eventually students would just forget about labs; they wouldn't bother doing them. They learn that they really don't have to do all the things you assign them. Then the class becomes less significant to them. I've been more lax some years when, you know, "I'll give you an extra day or two," but usually those things just drag on and on.

Learning responsibility appeared to be delicately related to the objective of taking class work and the teacher seriously. As we have seen, marking served as a traditional, extrinsic reward to reinforce responsibility and the work ethic.

In addition to marking students' work, all the teachers assumed it was their responsibility to encourage students to work hard. All teachers established a business-like atmosphere in their classrooms. Yet most enriched this basic atmosphere with other feelings that naturally emerged from their personal traits. In order to illustrate different classroom climates, I have selected two of the teachers who gave this enrichment a high profile in their classroom — Mr. Almon and Mr. Cheney.

As Mr. Almon moved around his room helping students with their work, I noticed that he consistently positioned himself in a way that guaranteed direct eye contact with the student. He listened actively and patiently. In the first class of the year, Mr. Almon emphasized "considerations for other people" when he went over the "Atmosphere and Rules" of his classroom (the classroom "constitution"). I discussed this with him:

Aikenhead: There's a high priority in your mind about how kids feel in your classroom. What are your objectives in this area?

Almon: Well, one reason I want them to feel good about the classroom is because I want them to feel good about science. . . . Science is an interesting subject, an enjoyable subject. . . . I found such a difference when I was in school. That atmosphere in a classroom made a difference to whether I enjoyed that class or whether I even worked in that class, or whether I fought the system. I get fewer students who will fight the system, or fight me personally, than I would get if I tried to make a more structural or authoritarian-type classroom. We do things like voting on when tests are. It seems to alleviate areas of conflict between students and teachers.

Mr. Almon coped with behavioural problems by showing concern for the student. This tactic usually had the effect of circumventing confrontations in the classroom. The "good-feelings" atmosphere, although it affected classroom behaviour, also enhanced Mr. Almon's curricular objectives.

Almon: So I like them to take away from the class, not just problem-solving skills and formulas, but a feeling for science and an understanding of the phenomena. They seem much more able to take away the things I've done a demonstration with.

Aikenhead: That makes you feel like you've accomplished something?

Almon: Yes, and I also like to have an atmosphere in the class with a little bit of enthusiasm and excitement about science.

The social climate in Mr. Cheney's classroom could be characterized by his full, warm smile that broke out spontaneously, especially when students needed to be put at ease. At the very beginning of the year, he made a conscious effort to establish personal contact with each student "before the atmosphere becomes more business-like around report card time." His dapper, three-piece, blue suit, his chatting with students in the hall, his questions about how students' mothers are doing, and his reminiscences with students over camping trips were part of the opening-day patter. Although his three-piece suit evolved into a two-piece suit and then into more casual dress, his personalized interaction with students continued throughout the months.

In each class at the beginning of the year, Mr. Cheney talked to his students about his guidelines of courtesy. "So feelings don't get hurt; feelings are important," he reminded them. Mr. Cheney was emphatic about admitting that what they knew in their hearts was as important to him as what they knew in their minds. These turned out to be more than opening remarks. He conducted his lower-ability biology class, for instance, by constantly referring to his guidelines on feelings, and explicitly acknowledging the students' feelings as well. His behaviour defined for them what his guidelines meant. In September, his lower-ability group constantly laughed at each other's mistakes. If someone in the hallway happened to trip or drop a book, the class would break out into gales of laughter. One girl was so shy about talking out loud, she stuttered and nervously twisted her hair as she spoke. Others were simply too scared to answer a question. By October, the class began laughing *with* Mr. Cheney, and the shyer students were offering answers quietly. By November, the class seemed to have matured considerably. Attendance was high. They cooperated in their learning activities. They were courteous to each other.

Obviously, Mr. Cheney meant it when he told me, "This bunch, they're quite special to me." His strategy for dealing with the student "product" related directly to the classroom climate he wished to maintain:

Cheney: Well, one of the things I told you this morning is that the lower academic group deal with product. If we concentrate more on product, it makes for all-round good feelings. I'm happy when they get something done. They're happy to get it done. They feel better about being able to do something. Whereas if you go into a situation where they just can't do it — and it's not a question of repetition and drilling or whatever — it's just not worth that kind of scene. Well, how can we come away with any kind of good feelings? At least here there are a number of things they're going to do. And some will do them extremely well. . . . The feeling is there, and yet [the work] is academic.

The classroom feelings and attributes described above were not the monopoly of Mr. Almon and Mr. Cheney. An atmosphere of support and concern for students was part of the climate in every science classroom at Prairie High. This atmosphere of support and concern encouraged both academic success and social success. While such an atmosphere served to fulfill teachers' aspirations, it also served as a subtle, though effective, behavioural guide for students. In the currency of classroom interactions, "feeling good" had motivational value and behavioural dividends.

Here we return to the purpose of the case study at Prairie High, in which particular attention was to be given to the viewpoints held by the science teachers themselves. This case study is meant to be *their* case study, in the sense that they could have written it themselves had they been given the appropriate time and assistance. Simply put, my function has been to bring their perceptions and beliefs into focus and articulate them in an organized fashion. My general method has been to observe classroom events, to ask about the decisions that led to those events, to inquire into the reasons behind those decisions, and to record the teachers' perceptions and beliefs that gave rise to those reasons. My task has not been to come to conclusions. Thus, this case study does not end with a series of conclusions, although it does suggest some directions a reader might follow.

Conclusions may be drawn by the reader. If the reader has an interest in school science curricula, but is not a teacher, then this case study illustrates, I believe, some — but only some — of the sensitive, complex and interrelated facets of teaching science in a high school. If the reader designs curricula or wishes to implement curricula, and if he or she gains a better appreciation for the teaching process as a result of this case study, then it will have already served a useful purpose.

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Statements of Council

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Canada's Threatened Forests, March 1983

Statements of Council Committees

Toward a Conserver Society: A Statement of Concern, by the Committee on the Implications of a Conserver Society, 1976, 22 p.

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Background Studies

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