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ABSTRACT

Canada is one of nearly 40 countries involved in the Second International Science Study (SISS). The Ontario Ministry of Education used the data generated in the study as a vehicle for assessing science education in the province, and comparing the province to the rest of Canada. Each chapter of this report contains a non-technical summary of findings. Specific areas studied include: (1) the teaching force; (2) science teacher professionalism; (3) research in science education; (4) policy documents; (5) student enrollments; (6) student achievement; (7) male and female achievement; (8) student attitudes to school and to science; (9) male and female attitudes to school and to science; (10) valuing science; (11) science laboratories; and (12) curriculum decision making. In general, it was found that Ontario students have positive attitudes about school and science but their achievement is not as high as might be expected of the richest province in Canada. In addition, Ontario shows innovation in curriculum decision making and exhibits more confidence in its local personnel than do other provinces. (TW)

RESEARCH BRIEF

ONTARIO SCIENCE EDUCATION REPORT CARD

Canadian National Comparisons

F. MICHAEL CONNELLY

This research report was funded under contract by the Ministry of Education, Ontario.
This study reflects the views of the authors and not necessarily those of the Ministry.

Chris Ward, Minister
Bernard J. Shapiro, Deputy Minister

Ministry of Education
Ontario

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PREFACE

For several years now, Canada has participated in one of the largest ever international curriculum studies, the Second International Science Study (SISS) under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). Close to 40 countries have been involved with the study at one time or another. Twenty-five of them, including Canada, have run the course from beginning to end. The Ontario Ministry of Education was interested in the project at the outset and provided additional support beyond the basic funding for the national study granted by the Social Sciences and Humanities Research Council of Canada. As a result the Ontario data on which this report is based are the product of a three-tiered structure: international, national and provincial. The basic ideas of importance to the study evolved first at an international level with a cross-disciplinary research team, secondly at a national level with a Canadian research team, and finally at a provincial level with an Ontario advisory committee. Accordingly, even though this is an international study, it is possible to treat the Province of Ontario as a separate unit, a de facto country, and make comparisons with Canada as a whole. However, since the basic structure and set of questions for the study were essentially set before local Ontario considerations entered the picture, the test instruments are not designed to reflect the particular characteristics of Ontario's science curriculum. A different study would undoubtedly have emerged had local Ontario concerns been the primary interest. For this reason it is important that readers of this manuscript know something of the international and national flavour of the study.

The context which justifies the conduct of IEA/SISS studies is national policy reform. By comparing science achievement across countries it is assumed that each country will learn things of importance for planning its own science education.

One of the values of the IEA/SISS approach to policy is that it is based on the view that reforms ought to be based, at least in part, on factual descriptions of the school system and its effects. Now, there is no doubt whatsoever that the SISS is extremely limited in what it has accomplished in this respect. Because its definitions are international, it is not sufficiently sensitive to any particular country or jurisdiction such as Ontario. Furthermore, there are no agreed-upon comparative education methodologies which make it possible to satisfactorily compare achievement from country to country. And finally, and perhaps most telling of its limitations, is the fact that while SISS has good descriptions of national school systems, including their curriculum policies, and a modest description of the achievement and attitudes of their science students, it has nothing of any real interest to say on classroom practices. There is still, therefore, a gaping hole in the SISS. But, for all that, the study provides something descriptive. It is not a mere collection of opinion, the driving force behind much curriculum policy reform. A positive sense of the potential of a different way of going about curriculum reform is revealed in this report. Thus, while readers are cautioned not to read too much into the achievement and attitude results that are eventually presented herein, these results are at least as interesting as public opinion on curriculum and so should not be dismissed entirely.

PROJECT STAFF

This report builds on the work of a national research team. The following people played significant staff roles.

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- Ministries/Departments of Education assisted through providing documents and other sources of information. Department personnel participated in interviews, assisted in the selection of school samples, validated sections of the report, and served as members of Advisory Committees.

- Districts/Boards of Education gave administrative consent for the conduct of our study in their schools and offered assistance beyond that requested of them. Board personnel completed survey instruments and participated in interviews.

- Principals and teachers contributed their time and support in Phase I knowing that they were committing themselves to greater time commitments in Phase II. Many offered additional assistance.

- Graduate students in the Western, Central and Eastern centres assisted in various aspects of the study. Many worked as volunteers in the trial testing of instruments and the validation of historical materials. Some assisted in survey preparations, data input, and library research.

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Chapter 1
THE STUDY IN CONTEXT

1.1. The International Context

The International Association for the Evaluation of Educational Achievement (IEA) is a voluntary organization of participating countries whose aim is to organize international curriculum studies in such a way that comparisons may be made between countries for the purpose of policy generation in those countries. IEA, formed in the late 1950s, claims to be unique in being "the only institution in the world set up not only to promote but also to carry out multi-national research in education" (IEA Brochure, undated). The association has carried out a number of studies of educational achievement across the world, focusing on the description of educational systems, on the evaluation of student achievement, and on how school and non-school variables affect educational achievement.

The first IEA studies were carried out in the 1960s and 1970s. Canada did not take part in the First International Science Study (Comber & Keeves, 1973). As a result there are no benchmark data in Ontario or elsewhere in Canada to make long-term comparisons as there are for other countries who participated in both studies. The director of IEA has, until the recent appointment of a new director located at SUNY in Albany, New York, been situated in Germany at the University of Hamburg. Each study launched by IEA is housed in the country of the International Project Director appointed to the study. For science, the Australian Council for Educational Research organized both the first (FISS) and second (SISS) studies.

Each participating country in IEA establishes an international research centre which is responsible for coordinating the work of various projects undertaken by that country. In Canada, the National Research Centre is located at the Ontario Institute for Studies in Education, which has coordinated three recent IEA studies: mathematics, classroom environment, and science. Abortive attempts have been made to involve Canada in other IEA curriculum studies.

Within Canada, there is no common pattern for the organization of IEA studies. The mathematics and classroom environment studies essentially define Canada as consisting of two countries, where the two countries were the participating provinces: Ontario and British Columbia in mathematics and Ontario and Quebec in classroom environment. The science study took a different course and set up a single national study involving all provinces and the Territories. This immensely complicated the organization and created difficulties but was tremendously valuable within the educational community since it is, we believe, the largest and most comprehensive Canadian curriculum study ever conducted. As George Ivany, Vice President of Simon Fraser University, a former professor of science education, says, "the authors, in attempting to describe the rich fabric of education in Canada, expose themselves to a great deal of criticism. Nonetheless, the data they have assembled will greatly enhance our knowledge of the state of science education in this country. The new directions charted in methodology will lead the way to improvements in the conduct of such research" (Ivany, 1985, p. xiii). Ivany goes on to say: "But with educational traditions varying by virtue of time of settlement and country of origin, and with the Canadian propensity for the preservation of a multicultural society, it is little wonder the task becomes herculean"

(p. xiv). In effect, Ivany is pointing out that the methodology (and lessons to be learned by people interested in doing cross-national studies, as the Council of Ministers might be) is of at least as much interest as are the results of the actual study. There is simply no Canadian tradition for studies of this scope. Research has tended to be localized. Thus, on the positive side of the ledger, the study should be read with a great deal of interest as to its potential for doing cross-national studies. But, hearkening to Ivany's caution, the results must be read with an unusually critical eye. Readers may be interested in my own confidence level in this manuscript. It is high for the policy description section and medium to low for the achievement and attitudes section.

1.1.1. Ontario in the National Study

In order to handle the complexity of the Canadian science study, three centres situated at the Ontario Institute for Studies in Education, the University of Alberta, and Memorial University in Newfoundland were formed under the respective direction of Professors Connelly, Kass, and Crocker. These individuals, variously augmented by others, formed a national coordinating committee for research teams set up at each regional site. Each team was responsible for the details of their region. For instance, the Western team had representatives from Saskatchewan, Manitoba, and British Columbia who met with the regional director in Alberta. The collection of schools to be involved in this study and other matters of this sort were handled at the provincial level following a plan of organization laid out in the Western region, and this plan, in turn, followed decisions made by the National Coordinating Committee on numbers of schools and teachers to be sampled. The National Coordinating Committee, of course, defined its procedures in terms of guidelines laid down for the overall international study. The upshot of all of this is that a complex international and national study was able to proceed with a reasonable amount of sensitivity to local provincial concerns. Thus, it was possible in Ontario to draw a sample of schools which reflected the public school structure of Ontario education. Undoubtedly, had the study been exclusively an Ontario study, or had it been exclusively a Canadian study, some significant differences would have entered. But there is enough local sensitivity in the overall methodology to make the study meaningful at a provincial level.

Ontario turns out to be a rather special case. The central region was originally defined as consisting of Quebec and Ontario. The results of the first phase of the study which describes the educational system and provincial curriculum policies (more on this below) did follow this two-province definition of the central region. But the Quebec government chose not to participate in the student achievement phase of the work. In one of those peculiarly Canadian things that happen, the Social Sciences and Humanities Research Council, believing that a special francophone study ought to be conducted, subsequently supported a francophone research team which ran a parallel national study, in full cooperation with our own, which did include Quebec. In this case, the study was university-based rather than government-based and proceeded with only the usual hitches. In cooperation with the francophone study, and two years after the national sample had been conducted, our research team surveyed anglophone students in Quebec. Because these results have only recently been obtained, they are not included in the national data described in this manuscript. In effect, then, Ontario is the central region for purposes of reported science achievement.

1.1.2. Research Purposes

The general purposes of the research are best seen in goal statements prepared by IEA/SISS (Keeves & Rosier, 1981) and by IEA/SISS Canada. The goals of the former are:

- to examine the status of science education around the world;
- to identify those factors which explain differences in achievement and other outputs of science education; and
- to examine changes in science education and outcomes since the First International Science Study was conducted in 1970.

IEA/SISS required each participating country to complete the following activities:

- The analysis of science curricula and the preparation of national case studies describing the progress by which science curricula are developed, implemented and supervised.
- The preparation, trial testing and revision of student achievement tests, student and teacher attitude questionnaires, and school background questionnaires.
- The preparation and finalization of plans for sampling student populations and for data analysis.
- The administration of testing and background instruments, and the analysis of data.
- The preparation of national and international reports.

Given this set of purposes, the aims of Canada's participation were stated as follows in the original research proposal:

- to cooperate in the IEA comparative science education study;
- to generate descriptive knowledge of Canadian science curriculum policy and practices;
- to compare Canadian science curriculum policy with science curriculum practice and generate knowledge of the relationship policy to practice;
- to integrate this knowledge with the results o the Science Council of Canada Study, thereby providing a knowledge base of policy and practices unparalleled in any other area of the Canadian curriculum;
- to influence and participate in world trends in science education and science education research;
- to develop national curriculum sampling procedures and a model for national curriculum research which will be of use in other curriculum areas;
- to extend the theoretical formulation and the empirical base of previous research by the principal investigators on the relationship between the mandated and achieved curriculum; and
- to establish a solid descriptive basis for further empirical, experimental and ethnographic research in science education in Canada.

1.1.3. Links to the Science Council of Canada Study

Liaison was established between the then ongoing Science Council of Canada Study (Orpwood & Souque, undated) and the Second International Science Study. The basic purposes of these two studies, although different, were complementary. Essentially, the Science Council of Canada Study was designed to influence policy and to stimulate discussion of science education in Canada. The Canadian SISS was primarily run as a research study, aimed at providing a database which policy makers might use. The Science Council study undertook some descriptive work which directly supplemented SISS work. It

obtained no achievement results but it did do a number of on-site case studies of science teaching in the schools. Altogether the three studies, our own SISS, the francophone SISS and the Science Council of Canada Study add up to a remarkably rich picture of science education in Canada. The book *Science Education in Canada: Policies, Practices, & Perceptions* (Connelly, Crocker, & Kass, 1985) provides the best available picture yielded by these efforts to date. This report, of course, focuses on the SISS work; to do justice to the Science Council of Canada Study, readers need to turn to their publications. No publications have as yet emerged from the francophone study which began at a much later date.

1.1.4. Phases in the Study

Ordinarily one would not want to burden readers with a description of the steps of the study. In this case, however, complete and thorough book-length publications are available on parts of the study and readers should know what they can and cannot turn to as a supplement for their reading.

Basically, the study was divided into two phases, a descriptive study phase in which national educational systems were described in detail and a student achievement testing phase. The first phase was designed to provide contextual material for understanding achievement results. One of the major criticisms launched against the results of the First International Science Study was that it was impossible to compare results from country to country because the educational systems varied so much: the apples and oranges problem. Yet, people marveled worldwide at how well the Japanese did and how poorly everyone else did by comparison. Comparisons were unavoidable. As a result, the Second International Science Study determined to provide thorough descriptions of each school system and of its curriculum policy and content as a backdrop to achievement results to be later obtained. In this respect, there are two important publications in Canada. The first, already noted above, *Science Education in Canada*, gives a detailed descriptive picture of science education in Canada in 13 chapters. An earlier parallel volume on Ontario was published (Connelly et al., 1985). Readers may, therefore, read either the Ontario report (available from the Ministry of Education as a project report) or the national report (available from the Ontario Institute for Studies in Education) for the descriptive contextual material. Because the national report is set up by region and by province within region, readers can obtain a picture of Ontario relative to other provinces in the national document. The fine-tuned detail, including topic-by-topic analyses of all of the curriculum guidelines, details of all teacher education programs in Ontario, and so forth are found in the Ontario report.

Phase 2 achievement results are not yet published. OISE has, in press, Volume 2 of *Science Education in Canada* (Connelly, Crocker, Kass & Lantz) which presents the results nationally. The Ontario data have been analyzed in a special way for this monograph, Report Card, to highlight Ontario compared to other parts of Canada. This material is found in a later section of this report.

1.2. The Educational System

1.2.1. The Teaching Force[1]

There are approximately 337,000 educators in Canada, roughly two thirds in the elementary school and

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[1] This section is based on SISS data, Connelly, Crocker and Kass (1985) pp. 39-46, 289-291, and Science Council of Canada data, Orpwood and Alam, 1984. The SISS data are based on provincial and national statistics as well as survey results and the Science Council of Canada data are based on survey results.

one third in the secondary school. Just under 15 percent of this force is given over to administration and, interestingly, there is about double the administrative commitment at the secondary school compared to the elementary school. Over one third of all Canadian educators are found in Ontario. The number of educators in Ontario is 70 times larger than that of the smallest province, Prince Edward Island, and 126 times larger than the number of educators in the Canadian territories. At the community college level Quebec has the highest percentage of educators of all provinces and territories followed by Alberta, British Columbia and then Ontario.

Right across the country, secondary school teachers have a stronger educational background than do elementary school teachers. In Ontario roughly 65 percent of elementary school teachers have university degrees, some 20 percent less than the secondary school. Ontario does not show the worst discrepancy but it is certainly not the best. Eight other provinces and territories have better overall teacher qualifications at all levels than does Ontario *and* the discrepancy between the elementary and secondary school is less in six provinces. Ontario is below the national average both at elementary and secondary school levels. Alberta has the highest overall average educational level of its educators and the smallest discrepancy in the educational background between the elementary and secondary schools. Another interesting figure in this respect is that the educational level differences between the elementary and secondary school teachers is accounted for almost entirely by discrepancies in the educational levels of women. The average educational backgrounds are almost identical for males in the elementary and secondary schools. It is among the women where the differences between the elementary and secondary school show up.

According to the Science Council of Canada study there is over a three-to-one ratio of female to male teachers in the elementary schools and a reversal the rest of the way through the school system, with roughly two to one males over females at the intermediate level and eight to one at the senior level. According to the SISS survey, Ontario's Grade 5 schools are more heavily feminized (56.3 percent female) than the Eastern (52 percent female) and Western (40 percent female) provinces. By Grade 9 the schools are dominated by males, with 84 percent male in Ontario, and 85 percent male and 81 percent male in the West and East, respectively. The male predominance goes up again at the Grade 12 level, except for the East. Eighty-eight percent of Ontario Grade 12 teachers in the survey were male.

The science background of teachers in the elementary school is limited right across the country. For Canada as a whole the Science Council reports close to 80 percent of all primary-junior teachers have no science courses in their background. Twice as many Ontario Grade 5 teachers, according to the SISS survey, have no science courses in their background compared to the West and the East (40 percent in Ontario versus 20 percent and 21 percent in the West and East, respectively). The odd thing about Ontario in this respect is that, although such large numbers of teachers appear to be dismally educated in science at Grade 5, over a fifth of Ontario Grade 5 teachers have greater than 10 science courses. These teachers probably have a university science major in most cases. Neither the East nor the West match this level of specialization. At the Grade 9 level a somewhat incredible 26 percent of Ontario teachers still have had no science courses, although this is not Canada's worst case situation. The East shows over a third of all Grade 9 teachers without any science background. Again, Ontario has a very large number of teachers (45 percent) with what appears to be a science major. At Grade 12 Ontario has the worst record, with 8 percent of science teachers with no science background compared to 4 percent in the West and 2 percent in the East. Ontario again ranks highest at the other end of the scale, with 86 percent of its Grade 12 teachers appearing to have a science major. From the Science Council work it would appear that for those teachers at all levels who have a science background it is a long while since many have studied science.

In this connection it is interesting to note that in answer to the Council's question, "If you had a choice would you avoid teaching science altogether?", roughly one in five elementary school teachers said "yes" and another 10 percent were not sure. Of the reasons given for not wanting to teach science *poor*

background followed by *lack of resources* were most often cited. *Dislike of science* was a factor for some. In general, though, it is poor background rather than poor attitude to science that seems to be the main worry of elementary school teachers.

1.2.2. Science Teacher Professionalism: Associations

The science teachers of Ontario are increasingly becoming a force for professionalizing the teaching force in science education. The Science Teachers' Association of Ontario (STAO) is the most significant body in this respect. STAO has professional rather than union purposes. The association conducts surveys, participates in the development of provincial item pools, sponsors professional development activities, writes policy position papers on science education and becomes involved in the curriculum development process. STAO has three principal aims:

- to stimulate and improve the teaching of science in Ontario;
- to coordinate the activities of its members; and
- to disseminate information related to science teaching to its members.

It has a membership of over 1,200 teachers, 500 more than the next largest group, the Energy Educators of Ontario. Eight other provincial organizations and three national ones, of which Ontario is a part, play important roles. The additional organizations are:

Metro Science Teachers' Association
Environmental Science Teachers' Association of Ontario
Ontario Horticultural Teachers' Association
Council of Outdoor Educators of Ontario
CAN-ED Conference
American Association of Physics Teachers - Ontario Chapter
Energy Educators of Ontario
Science Coordinators' and Consultants' Association of Ontario.

The national organizations are:

The Canadian Association of Science Teachers
The Canadian Association of Science Exhibitors
The Canadian Association for Science Education

1.2.3. Major Moments in Ontario Science Education

To the extent that public reports and commissions are an indication of interest in education, Ontario ranks at the top among Canadian provinces. Almost twice as many pages describing "recent events" since 1945 were given to Ontario as to any other province in the SISS book (Connelly et al., 1985). Many of these reports were on education more generally although almost all had some bearing on science education and some were on science education specifically. Some were on science per se and would have had an indirect effect on science education. Table 13 in the Appendix presents a summary of major moments in Ontario science and science education.

1.2.4. Major Educational Moments in Science Education Terms: An Historical Summary

Since 1950, the Ontario government has maintained a constant focus on the individual as the central concern of the educational system. Emphasis has been placed on the recognition of individual differences among students and on the support of appropriate educational services within the local community to accommodate these differences. The Ministry of Education has sought to develop organizational and administrative structures and processes which would support such a system and decentralize control over educational services.

During the 1950s, changes brought about increasing decentralization of educational services. An emphasis on preparation for citizenship, work, and post-secondary education was added to the existing focus on literacy and numeracy. The development of four program divisions within the school system reflected emerging ideas about the intellectual, emotional and social development of children. During this period, science was compulsory to Grade 10 with General Science being taught mainly in urban schools and Agricultural Science mainly in rural schools. Teachers were being encouraged to reduce the number of teacher demonstrations and increase the number of student experiments. The content of upper level courses in physics. chemistry, botany and zoology was controlled by the nature of departmental examinations.

Increasing numbers of students--the result of the baby boom and post-war immigration--brought about a shortage of both teachers and school facilities. An emergency teacher recruitment and training program was implemented and a school building program begun. The emergency training program did little to prepare science teachers to utilize the experimental methodologies advocated by science specialists but brought in many new teachers, some with professional experience in the applied sciences.

By the end of the decade, the major focus in science had turned to space exploration and technological advances. The cry was for greater excellence in academic studies, particularly in physics, chemistry and mathematics. In the 1960s, science programs, based on new United States and British programs, were developed to enhance the capabilities of good students, while General Science and a multidisciplinary course, Space and Men, were developed for general students.

During the 1960s, the most profound change occurred as a consequence of the Vocational Training Act, which reflected governmental concern, at both federal and provincial levels, about the quality and quantity of skilled manpower required for an increasingly technological workplace. Science education benefitted greatly from this expansion. The Vocational Training Act spurred the development of educational programs and the creation of the necessary facilities and resources, at the secondary level. This, in turn, placed additional demands on the post-secondary system for more occupational, technical and technological training programs, which expanded rapidly. At the same time, rising expectations about educational preparation for occupational training and rising demands for entrance to post-secondary institutions led to increased retention of students beyond the age of compulsory schooling and increased pressure on the system to modify the means for determining admissions to post-secondary institutions. Central examinations for Grade 13 were replaced by assessments made at the local school.

During this period, there was an administrative move from external expectation by Ministry of Education Inspectors to internal supervision by school board personnel. Former Inspectors became specialist consultants and later on, in the 1970s, became education officers with general consulting responsibilities.

Science received extensive attention during the 1960s. New curriculum guidelines, based on inquiry and experimental methodologies, were designed and implemented in the Academic and Technical

Branches and in all science disciplines. Different programs were developed for four- and five-year programs. The only omission was the design of special science courses for the two-year program. By the end of the decade, attention had shifted to environmental concepts and the interrelatedness among living and non-living things, between humans and their social and physical environments. This attention was fueled by the Hall-Dennis Report and resulted in immediate changes in Agricultural Science, later changes in Intermediate and Environmental Science courses and, ultimately, to changes in science-related studies in the Primary and Junior Divisions. By the end of the next decade, the concept of interrelatedness had been incorporated into the design of many science courses. Physics courses included biophysics. geophysics and physical chemistry; chemistry courses included biochemistry and geochemistry; and biology courses were modified to include extensive coverage of environmental concepts or were designed on the basis of an environmental approach.

During the 1970s, there was an increased push to decentralize more aspects of the educational system. A credit system was introduced to allow local schools to accommodate the differing needs of individual students. Local schools and teachers were encouraged to develop and use experimental courses in science. Various unsuccessful attempts were made to revise guidelines for senior biology courses. This decade was a period of expansion and experimentation, of philosophical and psychological discussions, and of disagreements about the best (or better) ways to use science education to prepare students for a world in which technological advances increasingly would take over traditional skilled work. All these were reflected in initial attempts to revise Intermediate and Environmental Science guidelines issued in the early 1970s. The interim guidelines met with strong resistance from classroom teachers, who indicated they wanted more guidance from the Ministry in terms of both content and processes. Ultimately, the Intermediate Science guidelines were revised to accommodate teachers' concerns; similar attempts to revise the Environmental Science guidelines were less successful.

The decade ended with great concern being focused on academic excellence, declining enrolments and economic restraints, and the effects these would have on science education. Science was viewed as one of the areas of study most likely to be adversely affected by the anticipated changes, with increasing class size and decreasing availability of science materials being the two major concerns.

During the 1980s, we see a return to compulsory credits, and the development of an Ontario Assessment Instrument Pool. There is increased emphasis on basic knowledge and skills in communications and mathematics, on being technologically literate, on being better prepared for the world of work, on understanding the nature of Canadian society and culture, on basic skills and attitudes about physical and mental well-being, and on new ways of educating and continuing the education of teachers. New curriculum guidelines in all science disciplines and educational divisions have become a priority for the Ministry of Education. The ROSE report of 1982 has had considerable impact on science curriculum. Students must now obtain 2 of 30 credits in science for an Ontario Secondary School diploma or one required course to receive the provincial certificate. An entire range of secondary school guidelines was put under development and is now in the process of completion. As a postscript to this account the government released a document, *Science in Primary and Junior Eduction: A Statement of Direction*, in the fall of 1986, in which it served notice that one of the government's priorities would be elementary science education.

Finally, new Ministry policies in three areas will affect science education. One priority will be to encourage the use of computers in the classroom, thereby changing the nature of some aspects of science education. Students may learn to analyze experimental data using computer programs of their own design. Computer simulations may be possible in areas previously reserved for elite schools and post-secondary institutions.

The second priority will be to ensure the provision of adequate services for students with special educational needs within local rather than segregated schools. The presence of handicapped students and slow learners may curtail some experimental work in the name of safety in the science laboratory. Exceptionally bright students may be streamed into advanced or enriched classes--a move which will benefit bright students but may prove less beneficial to students of average ability.

The third priority relates to the extension of French-language rights. There is a general lack of francophone science specialists, particularly in the Northern regions. Current solutions to this problem are less than satisfactory. Some francophone students receive their science education in English; others receive it from teachers trained in areas other than science. To make French-language instruction viable, a plan to recruit and train francophone science specialists will need to be developed.

1.2.4.1. Selected Professional Developments in Ontario Science Education

The public is inclined to notice government curriculum initiatives when evaluating programs in science education. Often left unnoticed are important professional developments. Two such developments are the formation of the Science Committee of the Ontario Curriculum Institute and the development of the Science Teachers' Association of Ontario in its current form. The Science Committee of the Ontario Curriculum Institute was formed in 1963. The Institute was formed by the Ontario Teachers' Federation as a result of recommendations by the Science Study Committee of the Joint Committee of the Toronto Board of Education and the University of Toronto. The Science Committee criticized existing courses, made recommendations for the revision of science guidelines and was involved in materials development. The Science Committee played a significant role in the importing and implementing of the American alphabet-soup programs (PSSC Physics, BSCS Biology, etc.) of the 1950s and 1960s.

With respect to STAO, an event of considerable importance was the reorganization of the Science Teachers' Association of Ontario over the period of 1971-1974. STAO's curriculum committee emerged as its most important and influential committee with sub-committees on science education policy, primary-junior division, intermediate division, biology, chemistry and physics. In 1974 STAO withdrew from the Ontario Educational Association and became independent. One of STAO's initiatives since that time has been to strengthen and to draw elementary school science teachers into its membership. Development of the support document *Science in the Primary-Junior Divisions: Curriculum Ideas for Teachers* was an outgrowth of a survey and report with recommendations to the Ministry of Education. Currently STAO publishes a section of its journal *Crucible* specifically for elementary school teachers, entitled *Elements*. STAO's official curriculum policy cuts across the entire curriculum.

1.2.5. Research in Science Education

In Ontario, as in other provinces and countries, the amount and impact of research on science education is, at best, limited. Still, we were able to locate a surprising number of studies in Ontario directly connected to science education, roughly 50 all told. None of these studies, of course, have the sweep and scope of the Science Council of Canada Study, nor the Second International Science Study. Most also focus on Ontario and on some sub-set of problems within science education. The areas of most importance in this research were standardized tests, achievement, attitudes, relationships between secondary and tertiary levels of schooling, teaching methods, and the role of the media. A number of these studies were commissioned by the Ontario Ministry of Education, and still others were conducted by specific boards of education. Although it is not possible to trace the effects of these studies, it is likely that they had some influence on policy makers as they were essentially policy studies. Given the fact that there are 10 faculties of education in the province, all with professors of science education, the level of research

is modest. Some of the work, of course, is theory-oriented and is not aimed at the influence of practice. Other reports included in the survey are not research at all but curriculum development reports. Connelly and Roberts at the Ontario Institute for Studies in Education, for example, conducted theoretically oriented curriculum development projects. Neither project had a great deal of influence over the science curriculum. Roberts in particular, however, has had an influence on how science teachers think about science education in the province. This influence has come through his teaching, field work, especially through the Science Teachers' Association of Ontario, and through a pyramid effect as some of his students have become professors of science education in other Ontario universities and have assumed positions of influence in the teaching profession.

1.3. Previewing the Report

Given this contextual backdrop, we are now in a position to rehearse the policy, achievement, attitude, and conditions for science teaching reported in the SISS. These problems are treated, respectively, in Chapters 2 through 5. We now turn to policy considerations.

Chapter 2
THE INTENDED SCIENCE CURRICULUM

The IEA structure for thinking of curriculum is captured by three terms: the intended, translated and achieved curriculum. According to Rosier and Couper (1981) these are defined as follows:

> The intended curriculum may consist of a detailed specification of content and processes or it may consist of more general guidelines. It is often directly associated with an explicit set of aims underlying the curriculum. It may include suggestions about methods of teaching of the curriculum...
>
> The most ambitious or thorough intended curriculum issued by educational authorities will have little effect on the education of students unless effectively translated into meaningful learning experiences of science teachers. This occurs at the level of the individual science classroom.
>
> The achieved curriculum indicates the extent to which individual students internalize the experiences that were planned and organized for them. This means, for example, that the students learn the content... (as)... described in the intended curriculum, that they develop competence in the specific practical and investigative skills, and that they adopt the intended attitudes.

It is the first and last of these that are described in this report. In this section an overview is provided of the detailed analysis of the intended science curriculum in Canada as prepared by the SISS team. Details are found in Finegold and MacKeracher's chapter, "The Canadian Science Curriculum" (1985).

2.1. Ontario Science Education Policy in a State of Flux

The general remarks on science curriculum policy in Ontario presented here follow from a detailed analysis of policy documents (Connelly et al., 1984). The detailed analysis of science education policy which was necessary as a backdrop to the IEA Secondary International Science Study took place at a time when there was considerable national ferment in science curriculum reform. This was especially true for the Ontario secondary school. Following the Secondary Education Review Project (SERP) and the follow-up documents, The Renewal of Secondary Education in Ontario (ROSE) and Ontario Schools: Intermediate and Senior Divisions: Programs and Diploma Requirements (OSIS), the entire science curriculum from Grades 7 upwards began a major overhaul at the level of policy. Numerous science curriculum policy writing teams were established and even now their work is in various stages of completion and documents are not yet fully public. This major reform was initiated under a former Minister of Education, the Honourable Bette Stephenson, and it has been carried forward with the new government under the new Minister of Education, the Honourable Sean Conway. Recently, Minister Conway announced an action plan for reform of the elementary school (Ontario Ministry of Education, 1986). Thus, the detailed description of Ontario science education, which forms the backdrop to the SISS Ontario data base, was dated even as it was written. Something done descriptively turns out to be an historical document. It is ever thus in the shifting field of curriculum studies.

2.2. An Overview of Ontario Science Education Policy

Science appears to be viewed from three different perspectives by the Ontario Ministry of Education. First, the fundamental skills of problem solving and decision making are enhanced through scientific inquiry skills. Therefore, science-related studies at all levels are to contribute to the development of such skills, and inquiry and experimental approaches are expected to be used in the design of any science curriculum. It is mainly from this perspective that science-related studies are conducted in the Primary, Junior and Intermediate Division.

Second, an understanding and appreciation of scientific principles and the nature of science is viewed as contributing to the practical and applied aspects of human endeavours through the use of basic concepts, resources, information and technology in the home, community and workplace. It is mainly from this perspective that the basic and general courses are conducted in Intermediate and Senior Divisions.

Third, a knowledge of scientific concepts, principles, theories, and models, and the ability to use skills and processes related to the experimental activity (in the laboratory or in the field) are essential to further studies in both pure and applied fields at the post-secondary level of education. It is mainly from this perspective that general and advanced courses are developed in the Intermediate and Senior Divisions.

2.2.1. Ontario Policy Documents Compared to Other Provinces

MacKeracher and Jantzi (1985) found very little similarity from province to province in the kind of documents used to express science goals and content. This is, perhaps, not surprising in a country where each of the political jurisdictions has control of its own education. They found, however, that there is a fair degree of similarity in the goals of science education. People, everywhere across the country, seem to want more or less the same things from science education, at least as specified by each province in its policy documents. But when we ask how those goals will be accomplished, we again find considerable variation from province to province. Content definitions of the different science areas vary and there is considerable difference of opinion over what aspects should be mandated and what aspects should be optional. If nothing else, this variability ought to be chastening for those who believe they have the truth about what everyone should know in science. Clearly, the "basics of science education" in Canada are partly defined politically, quite apart from the degree to which it is seen to be fundamental to the nature of science, children or society. It is the Canadian way.

MacKeracher and Jantzi make the interesting point that there are five different ways across the country of specifying science education policy. The five are "textbook based", "content based", "concept based", "objective based", and "activity based". Textbook based policy essentially defines the curriculum according to a preferred text. The content based tends to list subject matter topics in specific science areas. The concept based specifies overriding concepts and the objective based lists goals in terms of students. The activity based focuses on laboratories, experiments and so forth that students might be doing. Given that breakdown, Ontario secondary school curriculum is mostly content based. In this respect it is interesting that the content based method of specifying policy tends, subsequently, to drive the writing of textbooks. Intermediate Science and Environmental Science tend to be concept based and elementary school science in Ontario is objective based.

2.3. Methodology for the Policy Analysis

The analysis proceeded in a highly detailed and specific way outlined by Finegold and MacKeracher (1985):

1. All provincial policy documents in each of the science areas, and all general curriculum policy documents which specified science as part of their content, were collected.

2. Goal statements for all science documents at all K-13 curriculum levels were analyzed and related to general goals of education stated by provincial governments. These statements provided a philosophical-political matrix for the intended curriculum as defined in the ensuing curriculum analysis.

3. Each content topic for example, light, was divided into sub-topics and all documents for Grades 4 to 13 were analyzed for all sub-topics, for example, wave motion. Each sub-topic was recorded in one of four categories: "required", "suggested", "optional", and "not mentioned".

4. Results were aggregated for each of three curriculum levels: upper elementary (Grades 4 to 7 in British Columbia and Yukon Territory, and Grades 4 to 6 in all other jurisdictions); lower secondary (Grades 8 to 10 in British Columbia and Yukon Territory, Grades 7 to 10 in Ontario and Grades 7 to 9 in all other jurisdictions); and upper secondary (Grades 11 and 12 in British Columbia and Yukon Territory, Grades 10 and 11 in Quebec, Grades 11 to 13 in Ontario, and Grades 10 to 12 in all other jurisdictions).

5. The resulting 12 lists were combined so that every topic and sub-topic mentioned in at least one jurisdiction was included in the aggregated list. Different terms which appeared to be synonymous were reported under the most commonly used term.

6. The data for each province and territory were then entered in the master list to form a composite analysis of science curricula in Canada.

7. The analyses were validated by a team of science educators, consisting, wherever possible, of department of education officials and classroom teachers, from each province. The validators were asked to establish criteria, appropriate to their own province and curriculum guides, by which to classify the topics and sub-topics as "required", "suggested", "optional" or "not mentioned" in the documents for the three curriculum levels analyzed. They were asked to propose synonyms for comparable terms and to add topics or sub-topics if necessary to complete the analysis for their own province. Suggested modifications were incorporated into the tables.

8. Tabular material was converted to graphic format in response to the general question, "How can the information be organized into a coherent whole which fairly represents the Canadian science curriculum?"

9. Data within each discipline were reported, as far as possible, within the content categories recommended by SISS document 35 (Rosier & Couper, 1981). Modifications were made in areas in which Canadian curricula differed extensively from the conceptual framework provided by SISS/35.

10. The content areas within each discipline were grouped into general content categories, each representing a general area of study.

11. The curriculum documents of several provinces--notably Manitoba, Ontario, Quebec, New Brunswick and the Northwest Territories--were under revision at the time the tables were prepared. Some details may now be inaccurate, although the overall impression provided by the tables is unlikely to be much changed.

12. The francophone curriculum documents for New Brunswick were not compared to the anglophone documents to determine whether there were major differences which should have been noted in the tables. A recent review of the documents suggests that differences relate to teaching methods and conceptual or thematic approaches used, rather than to specific content.

Based on this detailed analysis the SISS team discussed three characteristics of the Canadian science education curriculum: the common curriculum, curriculum specificity and curriculum prescriptiveness. Readers wishing a detailed analysis of the common science curriculum will find province-by-province data as well as a summary account in Connelly et al. (1985).

2.4. A Common Canadian Science Curriculum?

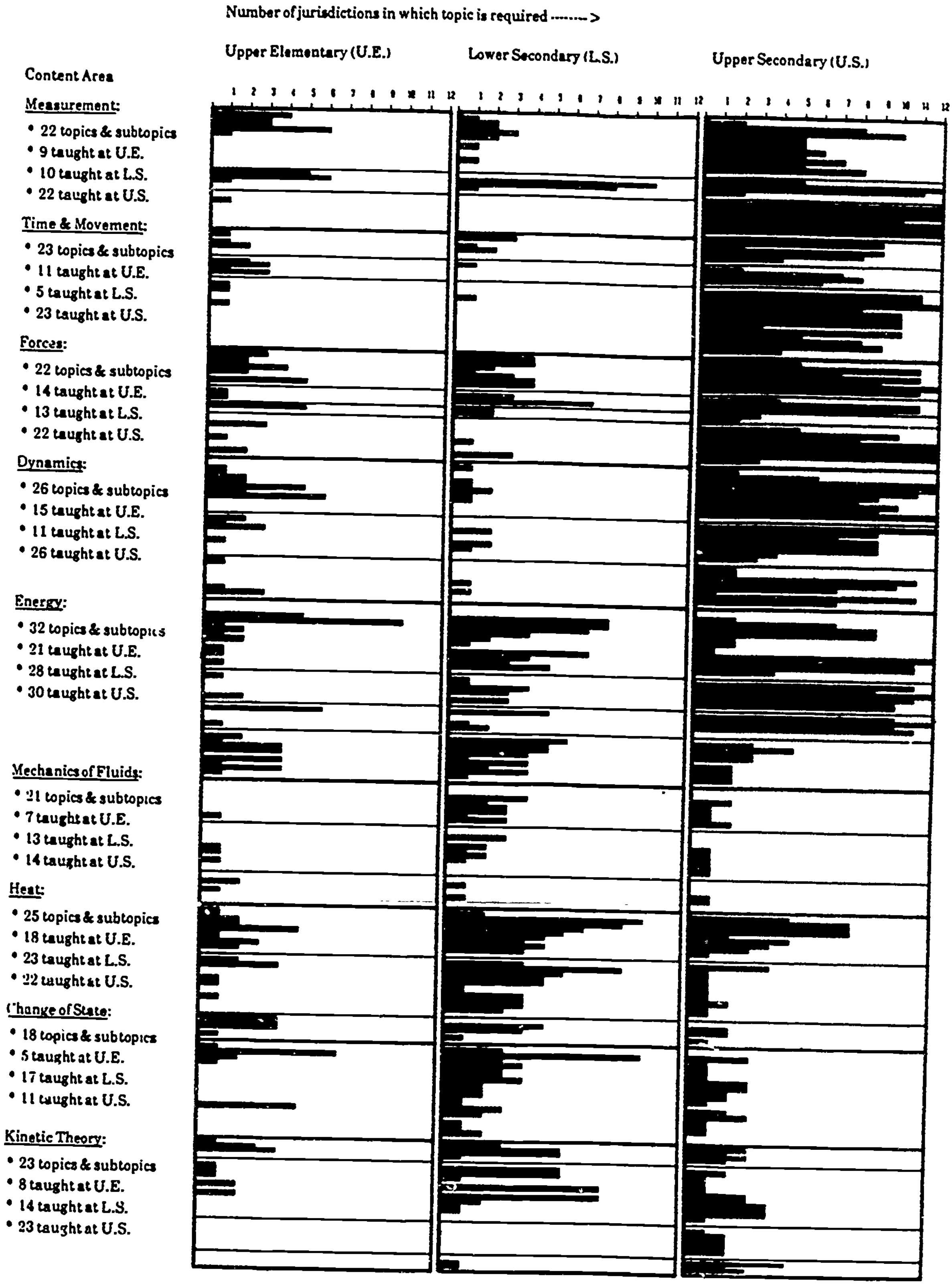
Given the diversity of documents across the country, we wondered how much commonality there was in the Canadian science curriculum. One way of getting at this question, following the 12-step methodology above, was to count up the number of political jurisdictions (provinces and territories) requiring specific content topics and sub-topics. Horizontal bar graphs were generated for each of the main school divisions (upper elementary, lower secondary, upper secondary) in which the number of Canadian political jurisdictions in which science topics and sub-topics were taught was plotted. Figure 1 taken from Finegold and MacKeracher (1985) is illustrative. From this figure it is readily seen from the amount of black representing the bars that there is far more commonality in the upper secondary school than there is either at the lower secondary school or the upper elementary level. Even from this selected page, it is clear that there is also a fair amount of variation from topic to topic. (There are many more topics in physics, not represented in this example.) There is, for example, very little commonality in kinetic theory, change of state, heat and mechanics of fluids at the secondary level. On the other hand, there is a surprising amount of commonality across the country at the secondary level in measurement, time and movement, forces, dynamics and energy. When this analysis is extended to other subject fields it turns out that the common curriculum is most extensive in chemistry over biology and physics at the upper secondary level and more extensive in physics over chemistry and biology at the lower secondary level. Biology has the least common curriculum across the country. This is, perhaps, as it should be, as biological studies are often taught more in relation to the environment and to society than are the other subjects and so they would tend to have more of a local character. Somewhat the same reasoning might account for the fact that there is so little common curriculum at the elementary and lower secondary level. These are levels where there tend to be more teacher initiative and autonomy and, in general, more attempts to make the curriculum meaningful for students. At the upper secondary level, subject matter comes to dominate and meaningfulness tends to take a back seat to objective content coverage.

In physics, major topics making up common curriculum across the country are measurement, time and movement, force, dynamics, energy and machines, light, wave phenomena, static and current electricity, and magnetism. There are fewer topics at the lower secondary school which define a common curriculum--measurement, energy, introductory heat, change of state; in the elementary schools common topics are energy, simple electrical circuity and batteries.

When the physics curriculum is grouped into main topics it turns out that classical mechanics accounts for the largest part of the curriculum (34 percent), followed by light, sound and wave phenomena (21 percent), electricity and magnetism (17 percent), heat and kinetic theory (16 percent), and modern physics (12 percent). The bulk (roughly two thirds) of the common physics curriculum in Canada is made up of classical mechanics. What this means is that more modern physics topics--problems of enquiry and science and society issues--tend to be sporadically treated.

For chemistry, the most common topics at the senior secondary school are laboratory skills and techniques, nomenclature, symbols and arithmetic, modes of inquiry, classification, identification and properties of matter, atomic structure, the periodic table and periodic trends in chemical properties, bonding, kinetic molecular theory, chemical and physical change, equations, qualitative and quantitative aspects of solutions, acid-base theories and properties of acids and bases, chemical equilibrium, oxidation-

Figure 1: The Common Curriculum: An Example from Physics[1]
(Mandated/Required Physics Topics and Subtopics)



[1] From Connelly, Crocker, & Kass, p. 156.

reduction reactions and electrolysis, chemical energy, reaction kinetics and thermochemistry, and carbon chemistry. There are far fewer, common topics at the lower secondary school--description, classification, and properties of matter and physical and chemical change--and in the upper elementary school the only common topic appears to be the description of matter.

Some topics seem to be taught in both chemistry and physics in some provinces. The underlying theory of molecules and the gas laws are noteworthy.

In general, the fewest common topics are found in biology. At the upper secondary school they are form, function, organization, physiology, biochemistry and reproduction of cells, green plant and small animal morphology, physiology and reproduction, various concepts related to the ecosystem, genetic continuity in populations and evolution. At the lower secondary level, curriculum is defined by the structure and physiology of cells and the human respiratory, circulatory and digestive systems. No topic in the elementary biology curriculum met our criterion of commonality. However, when the topic of reproduction and continuity of species is used to examine the curriculum it is clear that most provinces, at all levels, teach this topic in one way or another. In the early grades the topic tends to be treated using plants and simple animals; in the higher grades reproduction and genetic continuity are taught using plants and higher animals including humans. At the time the analysis was done the biology curriculum policy was so out of date that teaching bore surprisingly little resemblance to policy (Connelly, Enns, & Ben-Peretz, 1978). Therefore, we may imagine that even more human physiology and other relevant biology topics would show up in teaching compared to what appeared in the policy analysis.

We were able to get some idea of the earth sciences and here, it appears, that there is in effect no common curriculum across the country. General content areas such as the solar system, the universe, meteorology, and geology are variously defined and taught in different provinces, mostly at the elementary level. In some sense this is an anomaly since, according to the Department of Energy, Mines and Resources, there is a great deal of earth science research in Canada. Students confront earth science, when they do confront it, at the elementary school and then again, apparently, in graduate studies or research.

Environmental topics are found most often in biology, less frequently in chemistry and very infrequently in physics. Ontario has one of the higher emphases on environmental science at the elementary school and it appears to be used as a way of integrating the various subject sciences. One might imagine that this emphasis could be expanded to other provinces or to other parts of the Ontario curriculum. It is, after all, one way of teaching science to all students rather than specialty sciences to a select few. And it is also one way of developing awareness of an environment that the media claims is deteriorating. Environmental issues are becoming a major social preoccupation. Governments and communities are spending increasing amounts of time dealing with these matters. Furthermore, environmental science is easily taught as part of Canadian studies, the lack of which is a concern throughout the total curriculum, not only of science.

The idea of the common curriculum presented here tends, at least at the secondary school level, to counter the charge that decentralization in the Canadian curriculum leads to an unacceptable diversity, with everyone doing their own thing. There is a modest Canadian science curriculum, common across the country. This is most evident in the senior secondary school, less so at the lower secondary level and least so in the elementary schools. Still, as detailed as this work is, it must be treated cautiously. This is an analysis of policy documents, not of what is actually taught in Canadian schools. To the extent that there is a relationship the policy analysis is informative. But, as is well known in curriculum, there are many slips between the fork and the mouth. Another qualifier must be entered on the grounds that the upper secondary school courses which the policy documents represent are optional for most students. A senior

secondary biology course, for example, may be optional for students. Once the optional course is selected it still contains optional content. It is this latter aspect that our analysis tested. Therefore, the level of teaching and common curriculum policy as seen in our policy analysis will be greater than the level of common learning by Canadian students.

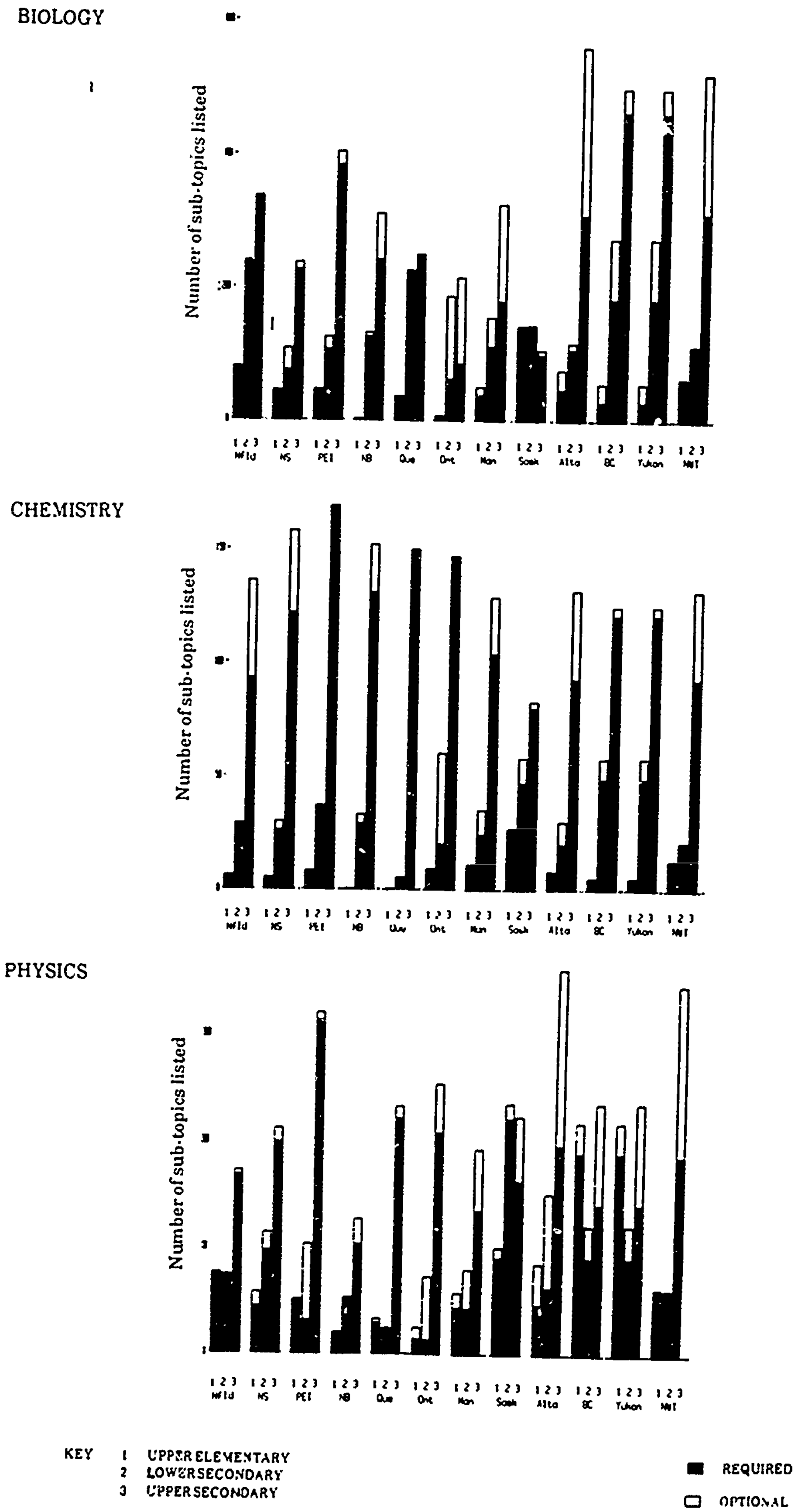
2.5. Specifying the Science Curriculum

Another interesting point emerged in the analysis in that different provinces, and different curriculum levels within provinces, tended to describe content in great detail in some cases and only generally in others. A detailed graphic analysis, Figure 2, was made of the amount of specificity introduced into the definition of topics across the provinces and for the three main curriculum divisions. From this it is clear that there is no common policy within and between the provinces on the matter. Alberta, for example, has one of the lowest levels of specificity at the elementary school level and provides the greatest detail of all provinces at the secondary school level. In all provinces the degree of specificity increases across the grades. Overall, Ontario is about average in this respect at the elementary and upper secondary levels and slightly above average in its degree of specificity at the lower secondary level. Saskatchewan appears to be the most consistent over all and maintains a low level of specification.

When subject fields are compared it turns out that biology is subdivided into sub-topics far more than physics, and physics in turn more than chemistry. Partly this may represent the policy makers' notion of how much time should be given to each subject. More topics may mean more time is intended to be spent on the subject. It may also represent the linguistic complexity in the field, with biology having by far the largest number of terms. This would not, however, seem to account for the discrepancy between chemistry and physics. One would assume that chemistry and not physics has the largest basic language. Again, with one exception, the greatest detail for each subject is provided at the secondary school. Saskatchewan is an interesting anomaly in this respect in that there is less biological detail specified at the upper secondary school than there is at either of the other two levels. Again, Ontario fits a general pattern--least specificity for each subject at the elementary level and most at the upper secondary level--and in general seems to be about average for each subject compared to other provinces. Provincial patterns do change for each subject, however. Alberta and British Columbia have the highest degree of secondary school specification in biology but less than the Maritime provinces for chemistry. Again, it is clear that the degree to which the science curriculum is defined into specific topics and sub-topics it is probably more a function of the specific committees chosen to write the policy than it is an attitude within the province or policy of the province. From the point of view of curriculum, it is clear that the definition of each subject, at least in terms of its least composition, is reasonably arbitrary.

We must conclude, therefore, that the depth at which a Canadian student will study a subject depends, in part, on the province in which the student lives. It is impossible to tell if there are significant conceptual and educational consequences of these variations. Given all of the other variations, one wonders if students' idea of science, what it is and how it is related to society and to themselves, differs in important ways across the country. Perhaps biology is not biology in Canada but, rather, Alberta biology, Ontario biology, Newfoundland biology. Given the Canadian way of doing things, it is likely that both views hold true. There is a common core of science understanding and there are also special views of science, and of its parts, from province to province. Ontario appears to tread a cautious national course in this respect, having neither the least nor the most specified science curricula.

Figure 2: Specificity in the Science Curriculum by Provinces and Territories[2]



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[2]From Connelly, Crocker, & Kass, 1985, pp. 169-170.

2.6. Prescribing the Science Curriculum

It was possible in the study to calculate a measure of the degree to which the science curriculum was prescribed across the country. For instance, while a province might define a subject in great detail, it might also make most of the topics optional. Thus, the picture of science that will emerge for a student would depend on the particular cluster of topics put together by a teacher and the particular selection patterns put together by the student.

Figure 3 graphically represents the Canadian picture. Looked at from the point of view of the provinces, and the subjects, it is clear that Eastern provinces tend to prescribe a larger proportion of the curriculum than does the West. Ontario shows the most variation in this respect, with a low level of prescriptiveness in biology and a very high degree of prescriptiveness in chemistry, more so even than in physics. Different subjects are fully described in some provinces--chemistry, for instance, in Quebec and Prince Edward Island. The same subject has only 71 percent of its topics prescribed in Alberta. Even greater variation within a subject is found across the country in physics and chemistry. Almost 100 percent of the physics curriculum is prescribed in Newfoundland whereas only half of it is specified in Alberta. Biology shows the greatest variation, with the least specification in Ontario at 38 percent and 100 percent in Quebec (all Ontario secondary school comparisons are now dated because Ontario has, since our data were collected, modified its secondary school science curriculum policy).

By comparing "specificity" with "prescriptiveness" it is clear that a propensity to describe a subject in detail does not necessarily reflect a prescriptive habit of mind. Alberta is one of the more interesting provinces in this respect in that it has the most highly *specified* physics curriculum and the least *prescribed* physics curriculum. On the other hand, Ontario is both highly *specific* and highly *prescriptive* with respect to its chemistry curriculum.

The three subject areas show interesting variations in Ontario with respect to the degree of prescriptiveness in the curriculum. The following comparisons refer to the total curriculum across all grades analyzed. Thirty-eight percent of the biology curriculum was prescribed in Ontario. This was, by far, the least prescribed biology curriculum in Canada--all other provinces ranged from a low of 61 percent in Alberta to 100 percent in Quebec. Because Alberta also had a much higher degree of specificity than Ontario, there were close to three times as many actual topics mandated in Alberta biology as in Ontario.

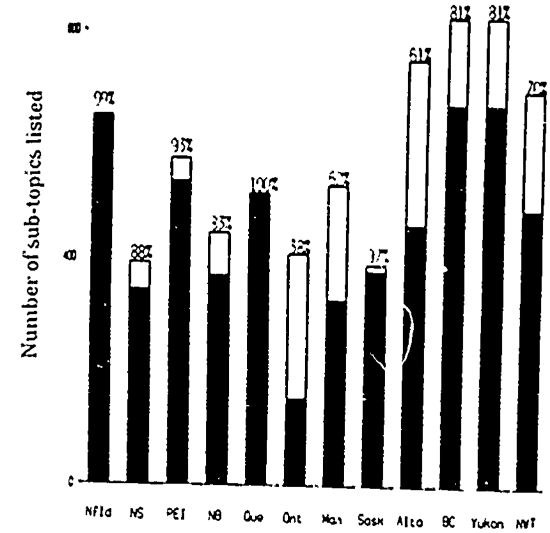
Chemistry is the most highly prescribed Ontario subject, with 81 percent of the curriculum required. This compares to the already noted 38 percent for biology and 60 percent for physics. Ontario also has one of the most specified chemistry curricula. When specificity and prescription are combined we find that there are only two provinces (Prince Edward Island and Quebec) which have more mandatory chemistry topics in their school curriculum.

Ontario physics prescription falls roughly in the middle, both in comparison with other subjects in Ontario and in comparison with other provinces for physics. Sixty percent of the Ontario physics curriculum was prescribed in our analysis. Other provinces range from 51 percent (Alberta) to 94 percent (Quebec). However, since Alberta's physics curriculum is more highly specified than Ontario's, there are still about a fifth more physics topics prescribed in Alberta than in Ontario. Overall, Ontario runs about average across the country in the total number of required topics and sub-topics, with Saskatchewan having the highest number and New Brunswick the least.

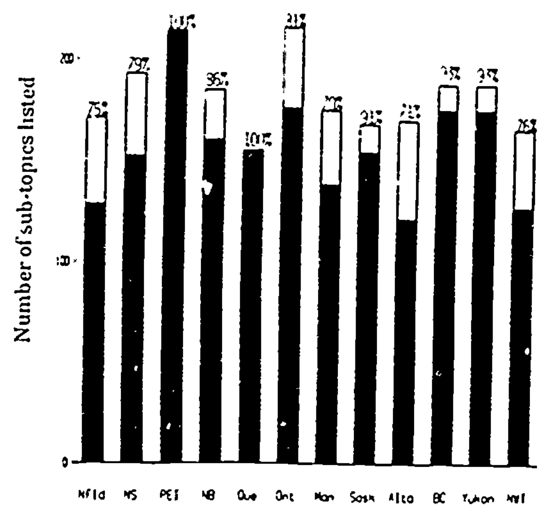
Full details on the prescribed Canadian curriculum are found in Connelly, Crocker, and Kass (1985).

Figure 3: Total Prescriptiveness in the Science Curriculum by Provinces and Territories[3]

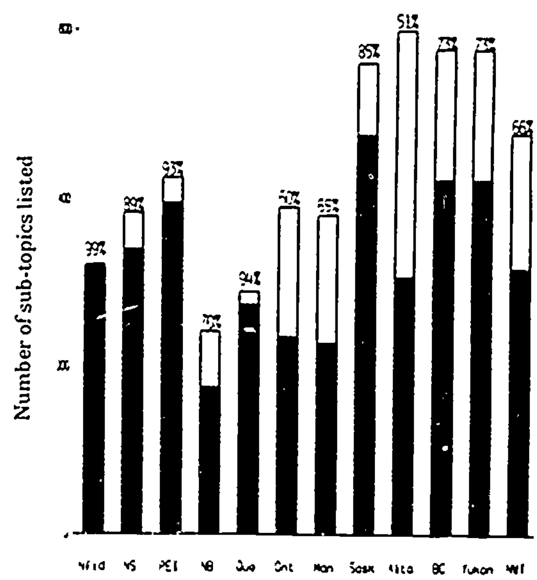
BIOLOGY



CHEMISTRY



PHYSICS



Percentage of required topics and subtopics is shown for each Province and Territory

KEY REQUIRED ■ OPTIONAL □

[3]From Connelly, Crocker, & Kass, 1985, pp. 171-172.

This analysis of the "intended" Canadian science curriculum completes Chapter 2 of this report. We now turn to the "achieved" curriculum.

Chapter 3
SCIENCE ACHIEVEMENT

Phase 2 of the Second International Science Study consisted of student achievement testing, along with the collection of data on associated school and student factors. Chapter 2 presents the achievement results, along with some of the more interesting findings on student attitude. Ontario achievement results are presented relative to national averages and to the highest and lowest performing provinces. This is a different breakdown than is being used to present the national results (Connelly, Crocker, Kass, & Lantz, in press). The national report makes comparisons according to the three regions--West, Central, East--that define the structure of the study. For the Ontario report it was felt that readers would be more interested in how Ontario did relative to specific high and low performing provinces. The identity of provinces is, of course, kept anonymous. International data, although undoubtedly of interest, are not presented. The reasons lie with the current state of the international study. Although Canada joined IEA/SISS some two years after its initiation, it is one of the few countries to date which has fully "cleaned" and weighted its data. Many other countries have completed their testing program but have not produced results in a form that would make easy and valid comparison with Canada. The international centre in Australia is currently receiving data tapes and undertaking the necessary checks to ensure that a valid set of international data is banked. At the time of writing this report our request to the international centre for access to comparative data for different countries was, therefore, for good reasons, denied.

3.1. What Populations Were Studied?

The international study defined three testing levels, one each at the elementary (Population 1), intermediate (Population 2), and senior secondary (Population 3) levels. Each country was given a choice of sampling by grade--5, 9 and last year pre-tertiary education--or by age--10-year-olds, 14-year-olds and an appropriate age corresponding to the last year pre-tertiary. There are considerable problems in sampling by age as not all children of a certain age are in a given grade. In practical terms it is next to impossible to withdraw all children of a certain age from their respective classes for sampled schools. As a result, the Canadian study was conducted on Grades 5 and 9 for the first two populations.

Population 3 is immensely complicated in Canada because school systems range in length from 11 to 13 years. Furthermore, Population 3 breaks down into three populations--biology, chemistry and physics--in which the last high school course for any one of the subjects may be taken at different grades. For instance, a student might take his/her last biology course in Grade 10 and his/her last physics course in Grade 13 in Ontario. Furthermore, because Grade 13 in Ontario was, at the time of sampling, effectively a pre-university year it contained a highly selected group of students. There were strong arguments to omit Grade 13 from the sample on the grounds that it would unfairly favour Ontario in comparison with other provinces. The decision ultimately to sample Grade 13 students was made by the Ontario Advisory Committee, whose members argued that Ontario Grade 13 students would normally be taking only their second course in biology, chemistry or physics beyond an introductory level. In other participating provinces it would be Grade 12 students who would be taking their second course in any one of the sciences.

Excluding Grade 13, it was argued, would, therefore, disadvantage Ontario compared to other provinces because Grade 12 students in Ontario would have less science than their counterparts in other provinces.

In all provinces, the credit system means not only that students may take their last course in one subject area in a different year than they take their last course in another subject area, but also that a student in Grade 11 might well be taking a Grade 10 chemistry and a Grade 12 or Grade 13 biology at the same time. Population 3 was eventually defined in Canada as those students registered in the final course of a particular science discipline as of the time of testing. The importance of the "at the time of testing" aspect of the definition is that many, but not all, secondary school students in Canada take their science on a semester system. The only way, therefore, to meet the IEA definition was to ignore both age and grade for Population 3.

3.2. Who Was Excluded from the Study?

When we compare the two bases of sampling, by age and grade, we find that roughly 30 to 40 percent, depending on the province, of 10-year-olds were excluded from the Grade 5 sample. These students range all the way from Grade 1 to Grade 7 and higher in special education classes. On the other hand, the Grade 5 sample includes from 15 to 30 percent, depending on the province, of students who are younger than age 10 and from 12 to 17 percent who are older than age 10. Likewise, at the Grade 9 level, roughly 45 percent of all Canadian 14-year-olds are excluded by the Grade 9 sample, and from 15 to 30 percent, depending on the province, of students younger than 14 years and from 15 to 30 percent of students who are older than 14 years of age.

There are further limitations on the study of importance to assessing results. To begin with, Quebec declined to participate in the achievement testing phase and so the national achievement results are made up of all provinces and territories except Quebec.

Also of importance is the fact that the study was restricted to publicly supported schools in the participating provinces and territories. This meant there were a number of schools and students excluded from the results, namely, federal schools (armed forces bases and Indian reserves), privately supported schools, schools for the handicapped and hospital schools. The effects of these various exclusions is seen in Tables 14, 15, and 16 (see Appendix). For Ontario these exclusions amounted to 4,038 students or 2.3 percent of the Grade 5 population, 3,440 students or 3.3 percent of the Grade 9 population, and 2,810 students or 3.9 percent of the senior secondary population. The exception to these exclusions was the Ontario Roman Catholic separate schools for Population 3. At the time of testing the Ontario Roman Catholic school system was defined as public to the end of Grade 10 and separate thereafter. The Ontario team determined to include the large Catholic system for Population 3.

3.3. How Large Were the School Populations from Which the Samples Were Drawn?

Enrolments for Grades 5 and 9 and for Population 3 are presented for each province and the territories in Tables 14, 15, and 16, respectively. Breakdowns in enrolments in the senior secondary population into biology, chemistry and physics are presented in Table 17 (see Appendix). For the year of testing there were 352,984 Grade 5 students in Canada. Almost 60 percent were in Ontario and Quebec. Just over 10 percent (11.1 percent) were in the four Maritime provinces and just under 30 percent in the four Western provinces. Ontario, with 121,365 students, is by far the largest province, having 34.4 percent of Canada's Grade 5 students. The general distribution is, of course, the same at Grade 9. There were 398,179 Grade 9 students in the year of testing, with a slightly larger percentage of them in Ontario and Quebec (62.3 percent) than was the case in Grade 5. There was a correspondingly slight percentage drop in the four

Eastern provinces (10.1 percent) and in the four Western provinces, (27.6 percent). The increase in the Central Regions' share is due to Ontario jumping to 37.4 percent of the total Canadian Grade 9 population.

According to our estimates there were 307,258 students in their final year of school enrolment in Canada. A smaller percentage were in Quebec and Ontario (55.2 percent), about the same percentage from the East (10.1 percent) and a larger percentage from the West (33.5 percent). The Ontario share had dropped dramatically to 23.4 percent, due undoubtedly to the fact that many of the sampled students were in Grade 13.

Although figures are quite imprecise we managed to estimate, to our satisfaction, the breakdown of Population 3 into biology, chemistry and physics. Our estimates are presented in Table 17, where it is seen that in Ontario, biology and chemistry are selected by a little over 33,000 students each and physics somewhat less at just over 28,000 students enrolled. In all but one other province (Alberta) biology enrolment exceeds chemistry by a significant number of students. There is no province in which physics has the highest enrolment. Ontario has the most evenly distributed enrolment across the three main subject fields of all provinces according to our figures. Biology and chemistry are for all practical purposes identical in enrolment in Ontario (33,140 students vs. 33,130 students) and physics is not far behind (28,100 students). Ontario has the lion's share of science enrolment for all subjects. The percentages for biology, chemistry and physics are, respectively, 39.0, 44.0 and 48.9. Thus, the proportion of students registered in science in Ontario is higher than Ontario's proportion of the total Canadian student population. Put another way, Ontario appears to attract a larger percentage of its students into science than do other provinces.

3.4. Getting Permission across the Country

The problem of obtaining permission to test school students across the country is tremendously complicated in Canada. Provinces vary radically in size and, therefore, in the direct interest Ministers of Education and high level government officials take in the details of a study such as ours. The first decision to be faced was whether or not it was important to gain the consent of the Ministry or Department of Education in each province. There were arguments pro and con depending on the part of the country, and eventually it was decided to make this a matter of regional choice. As a result most, but not all, of the provincial governments officially gave their approval to the study. Only one province objected, Quebec. It is interesting to note that the current francophone IEA/SISS study has proceeded without seeking official sanction from the Quebec government.

Whether or not official government approval was sought, a more or less standard procedure evolved for all provinces and was followed in obtaining specific classroom approvals. This procedure consisted of the identification of a random sample of schools in each province. Once that sample was drawn, sometimes in cooperation with government officials, letters were sent to the chief administrative officer of all school boards in which schools were selected. The letters explained the study, sought approval for the participation of the selected schools, and promised descriptive data on the schools in return. In most cases telephone contact was subsequently made.

The package sent to the chief administrative officer contained sample letters to the school principal and to participating teachers. Once approval was obtained, these letters were sent to each principal as a school package. Each principal was asked again to cooperate, although in a few instances a school's decision appeared to have been made at the board level. In most cases, however, board permission simply meant that the board would approve if the principal and teachers in the selected school would approve. Again, telephone contact was established with the principals. In cases of approval the principal selected

the teachers and was responsible for transmitting letters, test instruments, and results between the research teams and the teachers. In this way, anonymity for specific teachers and their classes was maintained.

3.5. How Large Was the Testing Program?

IEA/SISS specified that a sample of 20 schools for each of Populations 1 and 2 and for each of the subjects in Population 3 would define the national sample. Because of the complex political situation in Canada, where each province effectively acts as a country, the Canadian team determined to apply the international sample size of 20 schools to each province. This was not, of course, possible in Prince Edward Island which has only eleven secondary schools. Accordingly, from the point of view of Canada as a whole, the Canadian study is vastly over-sampled compared to other countries. Furthermore, because Ontario's size is so large compared to other provinces, the Ontario sample was quadrupled. Readers who are beginning to imagine the vast numbers of students sampled and the complicated mechanisms involved will appreciate the difficulties of national studies in Canada. It is as if Canada did 10 IEA/SISS studies, having analyzed the policies of 10 governments rather than one in Phase 1 and having tested for achievement in nine countries (Quebec excluded) in Phase 2 . Tables 1 and 2 give a summarized breakdown of the schools and students eventually tested.

The total Canadian sample consisted of 20,201 students located in 971 schools. Ontario with 7,525 sampled students and 359 sampled schools made up 37 percent of both the national student sample and the national sample of schools.

There were 5,151 Grade 5 students sampled in Canada, of whom 1,749 or slightly more than a third, were from Ontario. The Grade 9 population totalled 5,639 students, with 1,993 or 35.3 percent from Ontario. The remaining secondary school population consisted of 9,411 students divided roughly equally between biology (3,409 students), chemistry (3,110 students) and physics (2,892 students). The Ontario sample of 3,212 students again made up just over a third of the Canadian sample. The Ontario breakdown for biology, chemistry and physics was, respectively, 1,118 students, 1,110 students and 984 students.

3.6. Where Were the Tested Samples Located?

The location of the Ontario sample according to the total population of the demographic region is seen in Figure 4. This data was collected from the School Questionnaire, which was normally completed by a school principal. The question read:

What is the approximate population of the area where your school is located:

a. more than 1,000,000
b. 300,00 - 1,000,000
c. 100,000 - 300,000
d. 30,000 - 100,000
e. 1,000 - 10,000
f. less than 1,000

From Figure 4 we see that approximately 70 percent of each of the three sampled populations came from moderate population areas (1,000 - 300,000), close to 20 percent from very high population areas (greater than 300,000) and less than 10 percent from low population areas (less than 1,000). Undoubtedly this is due to the centralization of school populations in larger population centres at the secondary school level, almost none of our Grade 9 and senior secondary sample came from very small population centres.

Table 1: Grades 5 and 9 Target Populations and Achieved Samples: Numbers of Schools and Students[1]

Province	Grade 5				Grade 9			
	Target Population		Achieved Sample		Target Population		Achieved Sample	
	Schools	Students	Schools	Students	Schools	Students	Schools	Students
Territories	81	1,575	4	77	78	962	4	46
British Columbia	1,151	35,317	22	518	303	40 117	26	844
Alberta	1,308	32,974	22	615	557	33,332	18	673
Saskatchewan	801	15,119	18	414	456	15,205	14	298
Manitoba	522	14,678	13	218	277	15,166	13	236
Total	3,863	99,663	79	1,842	1,671	104,782	75	2,100
Ontario	2,209	117,327	77	1,749	617	145,566	75	1,993
Newfoundland	409	11,003	15	361	254	11,568	17	441
Nova Scotia	396	13,522	16	360	178	13,965	19	423
P. E. I.	49	2,014	15	428	20	2,176	13	418
New Brunswick	286	12,098	13	411	153	11,975	10	264
Total	1,140	38,637	59	15 60	605	39,684	59	1,546
Canada Total	7,212	255,627	215	5,151	2,893	290,032	209	5,639

[1] Figures are taken from D. Jantzi & D. MacKeracher (1984), *Sampling and Administration Report.*

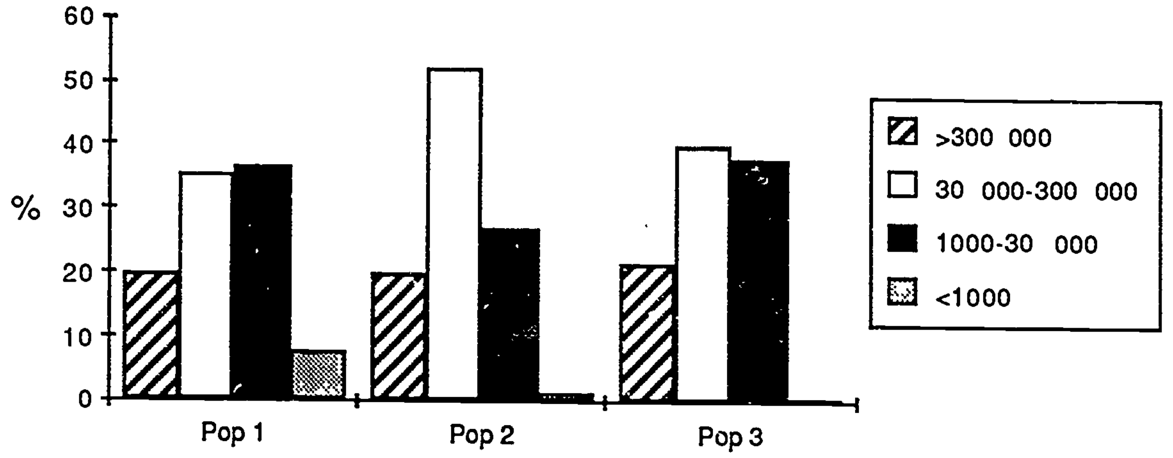
Table 2: Senior Secondary School Target Populations and Achieved Samples: Numbers of Schools and Students*

Province	Biology				Chemistry				Physics			
	Target Population		Achieved Sample		Target Population		Achieved Sample		Target Population		Achieved Sample	
	Schools	Students	Schools	Students	Schools	Students	Schools	Students	Schools	Students	Schools	Students
Territories	13	200	3	33	10	180	3	27	9	110	3	18
British Columbia	187	7,880	16	273	182	5,630	18	320	161	3,380	17	252
Alberta	242	14,210	17	353	241	14,550	14	319	212	8,120	16	277
Saskatchewan	264	9,790	16	212	288	7,010	16	227	256	5,990	14	175
Manitoba	147	5,120	18	247	147	4,680	17	217	74	3,390	16	262
Total	853	37,200	70	1,118	868	32,050	68	1,110	712	20,990	66	984
Ontario	569	33,140	68	1,297	566	33,130	72	1,277	560	28,110	67	1,209
Newfoundland	156	5,010	13	197	62	1,610	6	88	114	2,660	12	168
Nova Scotia	92	5,830	17	295	92	4,610	15	249	85	2,910	18	206
P. E. I.	11	1,020	8	266	11	690	7	182	11	460	8	128
New Brunswick	64	2,660	11	236	63	2,670	11	204	62	2,430	10	197
Total	323	14,520	49	994	228	9,580	39	723	272	8,460	48	699
Canada Total	1,745	84,860	187	3,409	1,662	74,760	179	3,110	1,544	57,550	181	2,892

*Figures are taken from Sampling and Administration Report, Jantzi & MacKeracher (1984).

Table 2: Senior Secondary School Target Populations and Achieved Samples: Numbers of Schools and Students

Figure 4: Population of the Area of Ontario Schools in Sample



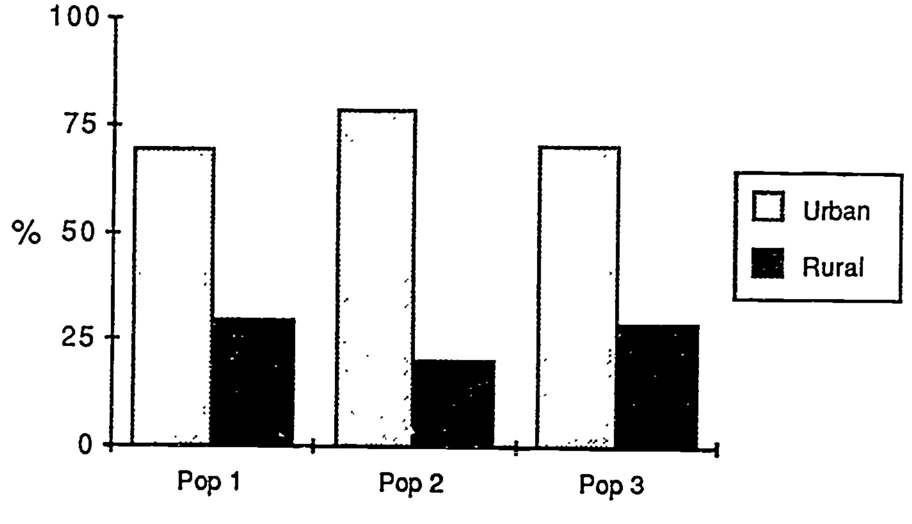
The school questionnaire also asked principals to specify, using four categories, whether their school was in a rural or urban setting. The question read:

Which of the following best describes the area where your school is located?

a. *an inner urban part of a metropolitan area*
b. *an outer urban/suburban part of a metropolitan area*
c. *an urban area but not part of a metropolitan area*
d. *a rural area*

In reporting the results we collected the first three responses to make the "urban" category. As Lai and Jantzi (in press) note, the "rural" category includes areas with populations up to 1,000 people and so includes small towns which have schools drawing from the surrounding rural area. Figure 5 shows that roughly 70 percent of the Grade 5 sample (Pop 1) and senior secondary sample (Pop 3) were in urban areas. Close to 80 percent of the Grade 9 sample (Pop 2) was urban. As might be expected the Ontario sample for all levels was more urban, by 15 to 20 percent, than was the sample in the East and in the West.

Figure 5: Location of Ontario Schools by Population



Tables 3, 4 and 5 give the average size of school sampled in each population for Ontario, high- and low-performing provinces and the national averages. The sampled Ontario schools are, not surprisingly, larger in urban than in rural areas: 301 versus 247 students in Grade 5; 1,065 versus 699 students in

Grade 9; and 1,127 versus 826 students in the senior secondary school. This condition holds up right across the country. What is interesting though is that the high achieving province has, by far, the largest average-sized urban schools in Grade 5 and the lowest performing province the smallest average-sized urban school. It is possible that the larger elementary schools had more teachers and other resources devoted to science. This relationship did not hold up at all at the Grade 9 and senior secondary levels however. Ontario has roughly twice as large average-sized urban schools (1,065 students) as either the high (467 students) or low (592 students) performing province. The difference, although still evident, is not so extreme at the senior secondary school level. It is clear that there is something different about how Ontario organizes its middle school compared to other provinces.

Table 3: Average Size of Population 1 Schools by Province and Location

	National	Ontario	High	Low*
Location				
Urban	310.2	301.3	341.2	184.0
Rural	229.9	246.6	210.0	234.1
Overall Average	274.4	285.1	247.5	229.9

*The apparent anomaly between Urban and Rural school size in the low-achieving province is due to the fact that this province had only one urban school in the study.

Table 4: Average Size of Population 2 Schools by Province and Location

	National	Ontario	High	Low
Location				
Urban	812.9	1064.9	466.7	591.5
Rural	374.0	669.2	243.2	325.0
Overall Average	628.1	974.7	387.8	373.5

Another figure that stands out in the three comparisons is the difference between the average-sized rural and urban school, the average urban school being roughly twice as large. At all levels, the highest achieving province has the greatest percentage difference in average-sized schools between rural and urban areas. Finally, Table 6 shows that for Population 3 the biology, chemistry and physics samples were drawn, respectively, from increasingly larger areas.

Table 5: Average Size of Population 3 Schools by Province and Location

	National	Ontario	High	Low
Location				
Urban	1017.7	1127.3	1078.3	689.8
Rural	506.8	825.5	494.5	313.4
Overall Average	790.8	1025.8	815.4	459.5

Table 6: Average Size of Population 3 Schools in Ontario by Discipline and Location

	Biology	Chemistry	Physics
Location			
Urban	1021.7	1109.1	1251.2
Rural	814.1	897.9	764.6
Overall Average	952.6	1046.3	1078.5

3.7. The Ontario Report Card

How did we do? Everyone seems interested in this question. Our interest reflects our educational history. first as students, then as parents wondering and worrying about our children. Everyone in the end seems concerned with report cards, whether of individuals (Mary's or Bill's) or collectively (boards', provinces' or countries'). Those report cards early in our school life seem to deeply affect how we look at education. We rarely ask, "Is school a good place to be?" Instead, we tend to ask "How did we do?" IEA/SISS was a study that, with most everyone else, asked this question. And like most everyone else, those of us who did the research were interested in the answer. Unfortunately, as already noted, we cannot as yet answer the question for Canada because international data are not yet available. But we do have an Ontario Report

Card (Table 7)[2] which compares Ontario to the rest of Canada. Let us begin with a warm up question. How difficult were the tests?

3.7.1. How Difficult were the Tests?

The tests seemed to be at about the right difficulty for Canada's Grade 5 and Grade 9 students, with approximately 60 percent of the students answering correctly at each level. At the senior secondary level, however, the tests were much harder for the Canadian students, with just under a 40 percent pass rate. So far, we do not have international comparisons to find out how difficult students in other countries found the test. We do know there was considerable variation within Canada and that will be discussed below. We also know that the test items were considered to be of reasonable difficulty by an international group of science educators. We also know that the Canadian National Team felt more or less the same way. Teachers were also asked a series of questions in an effort to find out whether or not they felt that their students had an opportunity to learn the content of the item being tested. Generally speaking, the analysis of these results was disappointing in that there was little discernable relationship between student achievement and teacher estimation of the students' opportunity to learn. As a result, we really do not know if Canadian teachers thought their students had a proper opportunity to learn the items. Given the ambivalent results, it is probably fair to say that there was no strong opposition to the tests among the teachers.

3.7.2. Ontario in the National Picture: How Did We Do?

In Table 7, the Report Card, Ontario is compared with the national average and with the highest and lowest performing province for each of the populations. Provincial scores were first calculated for the overall test results in Grades 5 and 9. Once the highest and lowest provinces were identified separate sub-scores were calculated for the biology, chemistry, physics, and earth sciences items. The procedure was different for Population 3, senior secondary, in that the top- and bottom-performing provinces were identified separately for chemistry, physics and biology. This procedure introduced one anomaly in that Ontario was the top-scoring chemistry province. The "high" province in senior secondary chemistry listed in the table is, therefore, the second highest province ranking under Ontario.

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[2] A Note on Weights

The sample for the SISS study was a simple random sample of schools within participating provinces and territories. Samples were selected independently for Grade 5, Grade 9, biology, chemistry and physics. The sample of students selected from the schools were more or less constant in that one class was selected per school in most cases. Because the sample was not self-weighting at the student or school mean level, the responses needed to be weighted by school size.

Furthermore, the sampling fractions in the principal strata (province and territory) were not constant so further weighting was needed to compensate for differing stratum sizes.

School weights were calculated as follows:

$$SCHWT = \frac{N(H)}{N} \; \frac{N(h.i)}{N(h.*)} \; \frac{n(h.*)}{n(h.i)}$$

N = total population
N(h) = population stratum h
N(h.i) = target population in school i of stratum h
N(h.*) = target population in sampled schools of stratum h
n(h.i) = achieved sample in school i of stratum h
n(h.*) = achieved sample in sampled schools of stratum h

NATIONAL	Biology	Chemistry	Physics	Earth Science	Average
Pop. #1	67.9	53.1	53.9	63.1	60.5
Pop. #2	63.0	55.3	62.6	60.5	60.7
Pop.#3	44.0	38.1	37.2	---	39.8
Average	58.3	48.8	51.2		

ONTARIO	Biology	Chemistry	Physics	Earth Science	Average
Pop. #1	67.7	50.5	53.4	62.6	59.9
Pop. #2	62.8	54.4	62.4	60.3	60.3
Pop.#3	47.7	42.5	40.0	---	43.0
Average	59.4	49.1	51.9		

HIGH	Biology	Chemistry	Physics	Earth Science	Average
Pop. #1	71.4	53.1	56.4	66.1	63.5
Pop. #2	66.6	63.8	68.0	62.8	65.9
Pop.#3	48.0	41.9	44.3	---	44.7
Average	62.0	52.9	56.2		

LOW	Biology	Chemistry	Physics	Earth Science	Average
Pop. #1	62.9	48.5	49.8	59.2	56.0
Pop. #2	57.7	49.9	56.4	56.8	55.3
Pop.#3	36.0	26.4	26.3	---	29.6
Average	52.2	41.6	44.2		

NOTE: *The high and low scoring provinces varied among the populations. Since Ontario was the highest in chemistry, the score for the high province is that of the second highest province. Row and column totals differ slightly because Pop.1 and 2 averages are the means of individual items, whereas Pop.3 averages are the mean of the three test scores.*

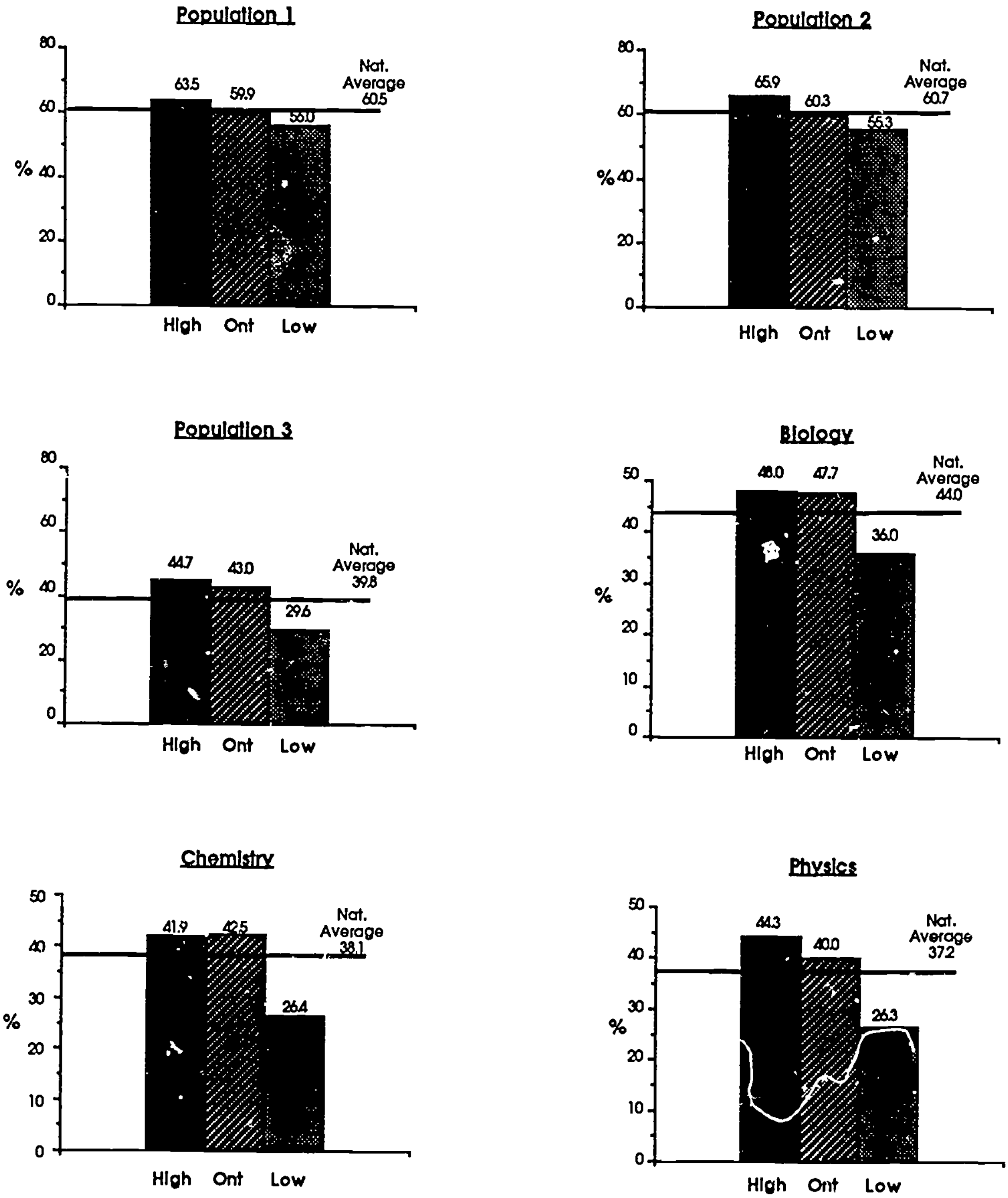
For most of us in Ontario, being slightly below average nationally is not satisfactory. Only ranking highest in senior secondary chemistry is also less than we might have expected. Finding that Ontario was not ranked as the worst in any test is small comfort. Because we might have harboured the illusion that Ontario was tops nationally, or even above average, our results are disappointing. Still, as we will see, Ontario students attitudes to school and science compare favourably with other provinces. Many will feel that a small sacrifice in achievement is a fair price to pay for more positive attitudes. Let us begin to break down these general remarks by examining a series of bar charts, Figure 6.

Ontario achievement at Grade 5 (Population 1) is slightly below the national average (59.9 percent vs. 60.5 percent). This is roughly mid-way between the lowest achieving province (56.0 percent) and the highest achieving province (63.5 percent). The position remains almost identical at the Grade 9 (Population 2) level where Ontario has crept 0.2 percentage points closer to the national mean. However, Ontario has fallen back in comparison with the highest achieving province (60.3 percent vs. 65.9 percent). Over 10 percentage points now separate the low (55.3 percent) and high (65.9 percent) provinces at Grade 9. At the senior secondary school (Population 3) level, scores drop right across the country. The national average is over 2[illegible] points lower than in Grade 9 (39.8 percent vs. 60.7 percent). Ontario takes the least dive at just over 17 percent (43.0 percent vs. 60.3 percent) when compared to Grade 9, a drop which is less by about 3 percent than the highest performing provinces and less by 8 percent than the lowest performing provinces. (Recall that the lowest and highest performing province for Population 3 is calculated as an average for the lowest and highest performing provinces in each of biology, chemistry and physics. In short, there is no actual province for the Population 3 high and low averages, although there is for each of the three separate subjects.)

On average, compared to other provinces, Ontario has crept up again and is now 3.2 percentage points above the national mean (43.0 percent vs. 39.8 percent). At this grade level, Ontario is close to the highest performing province (43.0 percent vs. 44.7 percent). Thus, although Ontario dropped further behind the highest performing province from Grade 5 to Grade 9, it closed the gap again at the senior secondary level. We will take a closer look at the subject fields below. At this point it is worth noticing that our senior secondary population, which broke down into three separate testing populations--biology, chemistry and physics--shows that Ontario is slightly above average in each subject. Chemistry students in Ontario, in fact, score higher than anywhere else in the country.

In interpreting these results, readers need to bear in mind that testing time was restricted and, therefore, a limited number of items were asked. It is possible, even probable, that had tests been designed for the Ontario curriculum, Ontario students would have done better throughout. The same, of course, holds true for any of the other provinces. We must also remember that testing in Grade 5 and Grade 9 is effectively a test of a sample of all students in school. For our senior secondary test, however, the population, especially in Ontario with Grade 13, is highly selected. Not only do students right across the country in general self-select into the subject field areas, but, in Ontario, the majority of students who were in Grade 9 have dropped out by the time of testing in the senior secondary school. For the test year 37 percent of Grade 9 students in publically supported schools four years later ended up registering in Grade 13 according to Education Statistics, Ontario. The remaining 63 percent have left school, although some (12 percent according to Education Statistics) are registered in the community colleges. It would take more careful analysis of the retention rates and who has actually selected these courses to determine how concerned we ought to be that Ontario did not walk away with the exam compared to other provinces. That was certainly one of the fears at the outset in this national study. There was some feeling, admittedly not shared by the Ontario Advisory Committee, that Ontario would automatically look good because it was essentially having college-level students tested in comparison with other provinces. But it did not not work out that way.

Figure 6: Mean Achievement for Ontario, High and Low Provinces with National Average by Population (Percentage)



Note: Ontario was highest in chemistry. For comparison, the second highest province is shown as the high province.

3.7.3. How Did We Do in the Separate Subjects?

There were no separate subject tests in Grade 5 and Grade 9, whereas the senior secondary level students were only tested in specialty sciences--biology, chemistry and physics. For the earlier grades, however, items were broken down into these three subjects and also earth science. In effect, then, we have separate scores for biology, chemistry and physics for all three tested populations and we have a score for earth science in the first two. It is of interest to see how the subjects do relative to one another at each level and across the curriculum. Please refer again to Table 7, Report Card, on which the following discussion is based.

There are few fixed patterns right across the grades. But one that stands out is that, students do better in biology than in chemistry and physics. There is not a single case where students score higher on chemistry or physics. This is true in Ontario and it is true for the highest and lowest performing provinces as well as the national average. It is also also true for each population--Grade 5, Grade 9, and senior secondary. These results seem related, at least in the senior secondary school, to the fact that biology students have more positive attitudes to their subject than do chemistry students to chemistry and physics students to physics (see discussion in upcoming pages). The dif nces show up quite dramatically when we calculate an Ontario biology score composed of biology achievement at each of the three tested population levels and then compare this figure with the other two subjects. Ontario biology students outscore chemistry students by 10 percentage points (59.4 percent vs. 49.1 percent) and physics students by a slightly lesser amount (59.4 percent vs. 51.9 percent). This spread between biology and the other subjects is a little larger in Ontario than it is in the highest performing province and lowest performing province as well as being slightly larger than the national average. While we are examining this particular set of figures it is interesting to note that the difference between the physics score and the biology score is greater in Ontario than it is in either of the higher or lower achieving provinces and higher than the national average. This means that in comparison with the other subjects, physics students in Ontario are not doing as well as they are in the rest of the country.

It appears, therefore, that when we break the science scores down into the various subject fields and compare the results with the other provinces, the Ontario physics curriculum needs the most work and biology needs the least. Because chemistry students did so well at the senior secondary level compared to other provinces, it is clear that priorities must be set for chemistry. Attention should be paid to its teaching in the lower grades. The major chemistry discrepancy occurs in Grade 5.

Once we remove biology from the picture, having established it as the highest performer of the three subjects, we find that physics and chemistry generally follow in that order although not necessarily so. When the three populations are averaged, Ontario students do about 3 percentage points better in physics than in chemistry (51.9 percent vs. 49.1 percent), and this seems to represent a pattern for the approximate level of difference between the subjects for other provinces as well. When we look more closely, however, we find that this is largely due to patterns in Grade 5 and Grade 9 in which students do better in physics than in chemistry both in Ontario and in other provinces. But at the senior secondary school level the pattern tends to reverse with students doing better in chemistry than in physics (42.5 percent vs. 40.0 percent). The difference between chemistry and physics is greater in Ontario than it is for the national average. For the poorest performing province, the two subjects are almost identical (26.4 percent vs. 26.3 percent) and for the highest performing province physics reaffirms it supremacy over chemistry (44.3 percent vs. 41.9 percent). Thus at senior secondary level it appears that physics students have tailed off in comparison with students in other science subjects whereas chemistry has strengthened itself relative to physics.

Finally, let us add earth sciences to the picture at Grades 5 and 9. Whereas all the other subjects show a slightly higher score in Grade 9 than in Grade 5, earth science drops a few percentage points. The greatest drop occurs in the highest performing province. Ontario is almost at the national average in earth science but still scores 4 percentage points lower than the highest performing province. In all cases biology still remains the top-performing subject but in Ontario earth science squeezes out chemistry for third spot, keeping it at the bottom in Grades 5 and 9. In other provinces, earth science finds itself in different positions: right after biology for the top and bottom performing Grade 5 province and at the bottom in the poorest performing Grade 9 province.

3.7.4. How Do Males and Females Compare in Science Achievement?

In a the nut shell, males did better than females although, perhaps, not by so much as some of us thought they might. The comparative success of males over females in science is well known, with the result that we may tend to exaggerate the difference in our minds. Weighted scores are represented on the series of bar charts for each population (see Figure 7). The differences seen between boys and girls is presented in Table 8, calculated as males minus females. As a result, a positive number means that males did better and a negative number means that females did better. Figures 8 and 9 present these same results graphically.

Table 8: Differences in Mean Achievement Scores for Males and Females

	Pop.#1	Pop.#2	Pop.3(avg.)	Biology	Chemistry	Physics
National	3.8	5.2	4.5	3.0	5.4	5.2
High	3.2	8.6	2.1	-0.1	6.4 *	0.0
Ontario	4.0	5.6	5.4	3.4	5.6	5.9
Low	-2.0	4.4	4.2	1.3	6.6	4.7

*Ontario was the highest in chemistry. For comparison, the second highest province is shown as the highest province.

In Ontario, males did better than females right across the board. The difference between the scores rose slightly from Grade 5 to Grade 9 (from 4.0 percent to 5.6 percent difference) and then tapered off. Two things stand out about these facts. The first is that performance differences show up so early in the school system. For the most part Grade 5 students have not reached puberty, and so one of the most noticeable and powerful differences between the sexes has not yet expressed itself. The second observation of note is the persistence of these differences. From a biological and cultural point of view we might have imagined a sharp spread in scores after puberty and as dating and other gender patterns developed. There is some hint of this in the greater differences at Grade 9. However, the senior secondary results show mostly stable differences. Two things of importance are happening here, however. Students generally select subjects in which they have an interest and males and females tend to select different subjects with more females choosing biology and more males choosing physics. The effect of this selection process should be to reduce the differences between science achievement for males and females. Finally, the differential achievement picture for males and females is complicated by the fact that females generally have a better attitude to school, although not necessarily to science, than do males, a point discussed later in the section on attitudes.

Figure 7: Mean Achievement for Ontario by Population and Gender

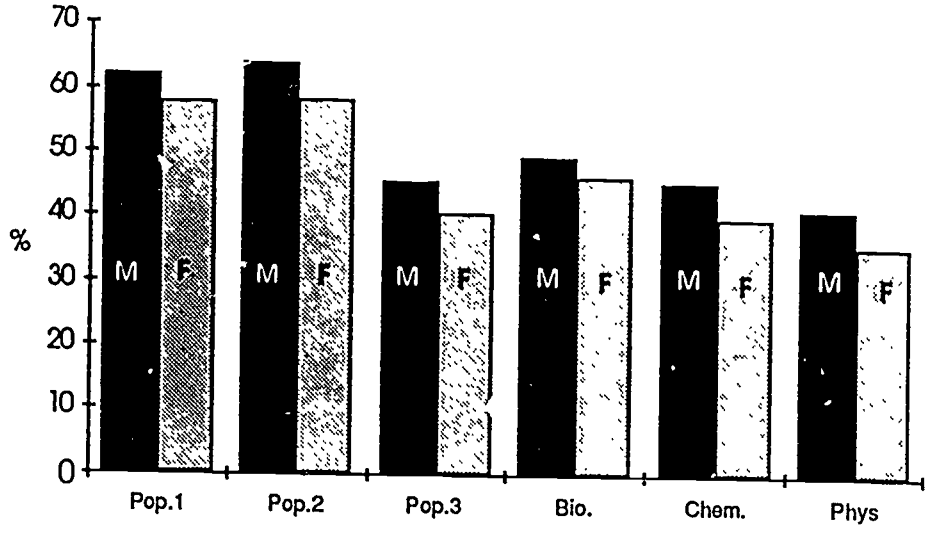


Figure 8: Male/Female Mean Achievement in Ontario by Population

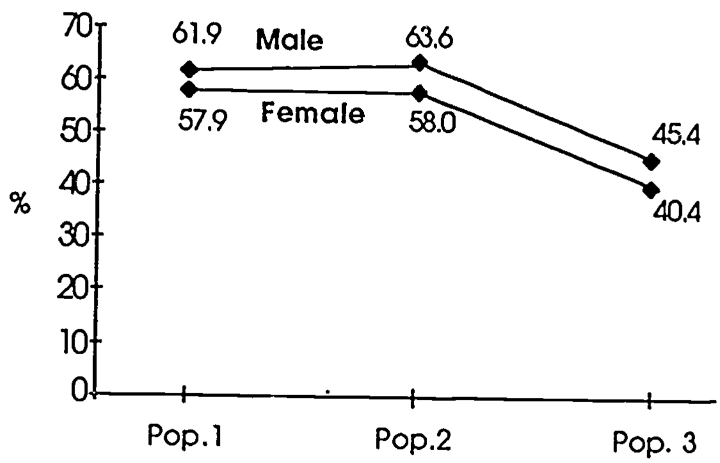
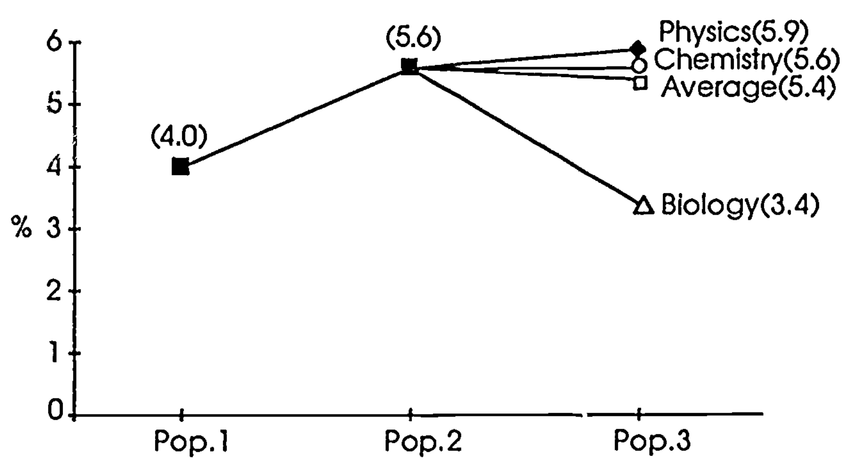


Figure 9: Differences in Mean Achievement of Males and Females in Ontario by Population



The early and consistent differences between Ontario males and females is more than a local phenomenon. Table 8, which records the differences between males and females for high and low provinces, as well as Ontario and the national average, shows that nationally the same pattern holds. There are two anomalies, however, which suggest that factors other than those we have explored may be at work. First, Grade 5 girls actually out-scored boys by 2 percentage points in the lowest achieving province. Second, at the senior secondary level females very slightly outperformed males in biology.

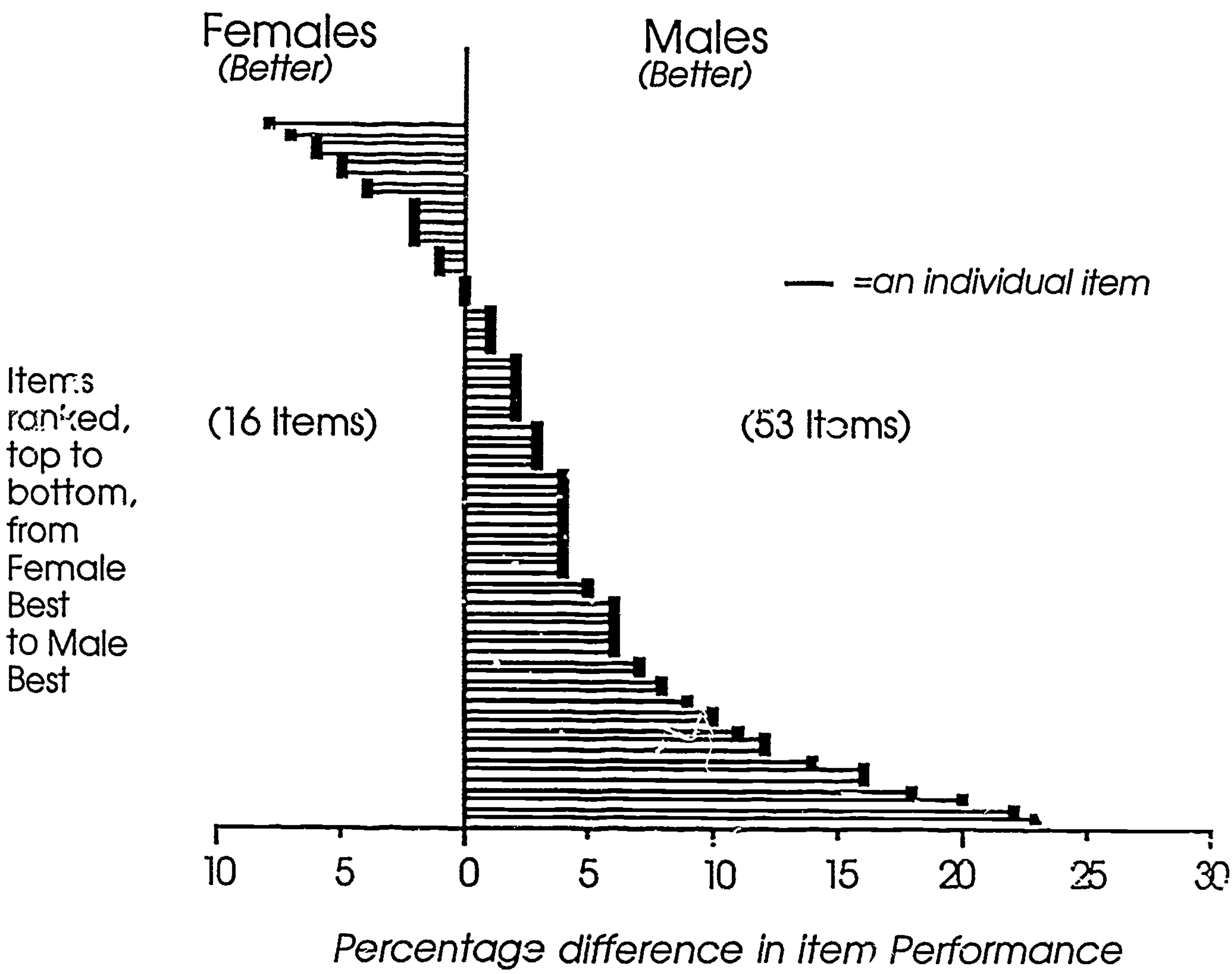
If we consider it desirable to equalize achievement between the sexes (a point I question in the conclusion to this section on male and female achievement), then Ontario appears to be getting off to a worse start than other provinces. There is a greater Ontario difference between the sexes' achievement at Grade 5 than for either the highest or lowest performing province and the national average. This situation is somewhat mixed throughout the years, however. Ontario shows the greatest sex differences in achievement in senior secondary biology and physics in comparison with the national average. However, at Grade 9, whereas the Ontario sex difference exceeds the national average it is less than the sex difference in the highest performing province. Something similar shows up in senior secondary chemistry, where the second highest performing province (Ontario was highest) shows a greater difference in achievement between males and females than does Ontario.

When the senior secondary results are broken down according to the three subject areas, physics has considerably larger sex achievement differences in Ontario than does biology and slightly greater than chemistry. Given the fact that these are self-selected subjects, and that there are more females than males in biology, one might have expected even lower differences here. On the other hand, this works both ways. We might expect that, given the social pressures, any female who selected physics would feel an extra competitive edge while in the course and this, overall, would tend to reduce the differences between males and females. This line of thinking is clearly not helpful, however, in sorting out the reasons for Ontario results. But for the high-performing provinces this thinking seems to work fine. Here, we notice that females did, in fact, do very slightly better than males in biology and that there was no difference whatsoever for males and females in physics. The difference between Ontario senior secondary males and females in physics (5.9 percentage points) and males and females in the high-achieving provinces (0.0 percentage points) is so striking that one wonders if there is something about the Ontario physics curriculum or teaching staff that might account for this performance. We are also led to wonder what it is that the high-performing province does in biology and physics to so sharply reduce the edge males have in science. Ontario chemistry, although not doing very well in this regard (5.6 percentage points separating the sexes), did not do as badly as did chemistry in the second highest performing province (6.4 percentage points separating the sexes). These results would be interesting to explore in more depth as the high performing province in chemistry is, in fact, Ontario.

Figures 10, 11, 12, 13 and 14, examine male-female differences in Ontario from the point of view of individual items. These graphs show on which items males or females did best and by how much. Overall, considering all three tested populations, males did better on 76 percent of the items and females on 24 percent, with 4 percent of items showing equal achievement. On this basis Grade 5 and Grade 9 are almost identical, with 22 percent and 21 percent of the items showing better performance by females.

At the senior secondary level females were trounced in physics, outperforming males on only 3 items. Oddly, or so it seems, biology, in which females did better in 7 of 35 items, holds fairly firm compared to Grade 9. Females outperformed males on 9 chemistry items, that is, 25 percent of the set of 35 items. From the point of view of the number of items tested, secondary school chemistry in Ontario offers the least advantage to males over females. Remember, however that the difference between the average overall score for the sexes was greatest in Ontario chemistry. From this point of view females are most disadvantaged in Ontario chemistry.

Figure 10: Ontario Population 1.
Items on Which Males and Females Did Best and by How Much



Stems for the Top 3 Multiple Choice Items

Female

1. Some seeds germinate (start to grow) best in the dark, others in the light, while others germinate equally well in the dark or the light. A girl wanted to do an experiment to find out to which group a certain kind of seed belonged. She should put some of the seeds on a damp newspaper and :

2. Which part of the following lists is composed entirely of animals?

3. A butterfly sitting on a leaf laid some small eggs. The pictures show changes that took place to the eggs. In what order do these stages occur?

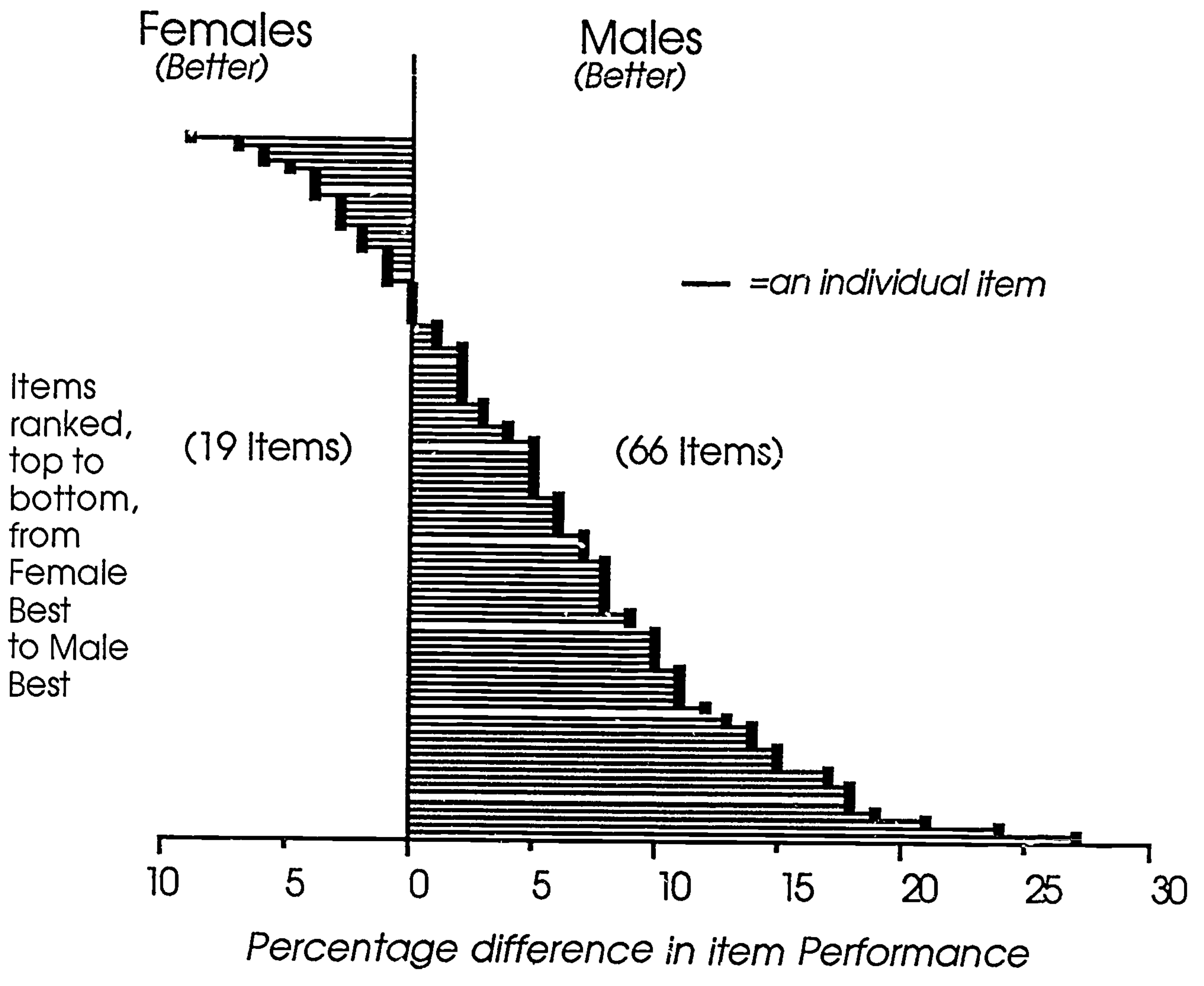
Male

1. Look carefully at the diagrams below. Diagram 1 shows that three equal weights are needed to balance a tin of fish. Diagram 2 shows that two tins of fish balance one bag of rice. How many weights are needed in Diagram 3 to balance the bag of rice?

2. The following diagrams show a dry cell (flashlight battery) and a bulb connected by wires to various substances. Which of the bulbs will light up?

3. A flashlight holds two batteries. In order to make the flashlight work, in which of the following ways must we place the batteries?

Figure 11: Ontario Population 2.
Items on Which Males and Females Did Best and by How Much



Stems for the Top 3 Multiple Choice Items

Females

1. Which of the following organs is not situated in the abdomen?

2. Years ago farmers found that corn plants grew better if decaying fish were buried nearby. What did the decaying fish probably supply to the plants to stimulate their growth?

3. Which of the following foods contains the most protein per kilogram?

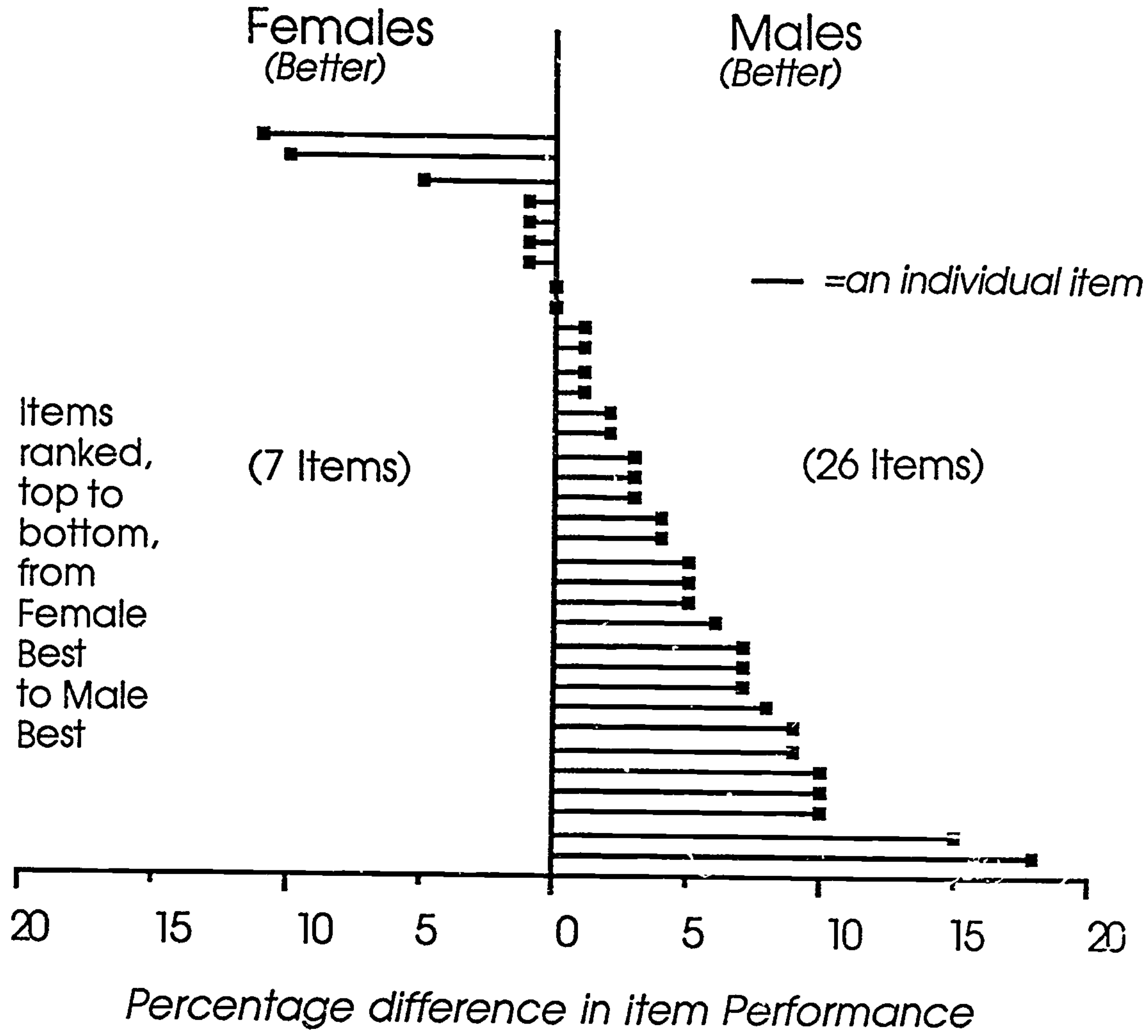
Males

1. Which diagram best shows what happens when light passes through a magnifying glass?

2. The crews of two boats at sea can communicate with each other over short distances by shouting. Why is it impossible for the crews of spaceships a similar distance apart in space to do this?

3. X,Y and Z represent three lamps in a circuit, which also includes a battery and a switch S. When the switch is open, X fails to light while Y and Z both light. Which one of the following circuits will produce this result?

Figure 12: Ontario Biology (Pop. 3).
Items on Which Males and Females Did Best and by How Much



Stems for the Top 3 Multiple Choice Items

Female

1. What initially determines whether a human baby is going to be a male or female?

2. This question is based on the following human pedigree of a sex-linked trait, colour blindness. Which person(s) could have no genes for colour blindness?

3. Two alternative colour characteristics in rats are "hooded" and "white". When homozygous parents of both colours are crossed, all the offspring are hooded. If these F1 hooded rats are mated together and produce litters totalling 50 rats, which of the following proportions is most likely?

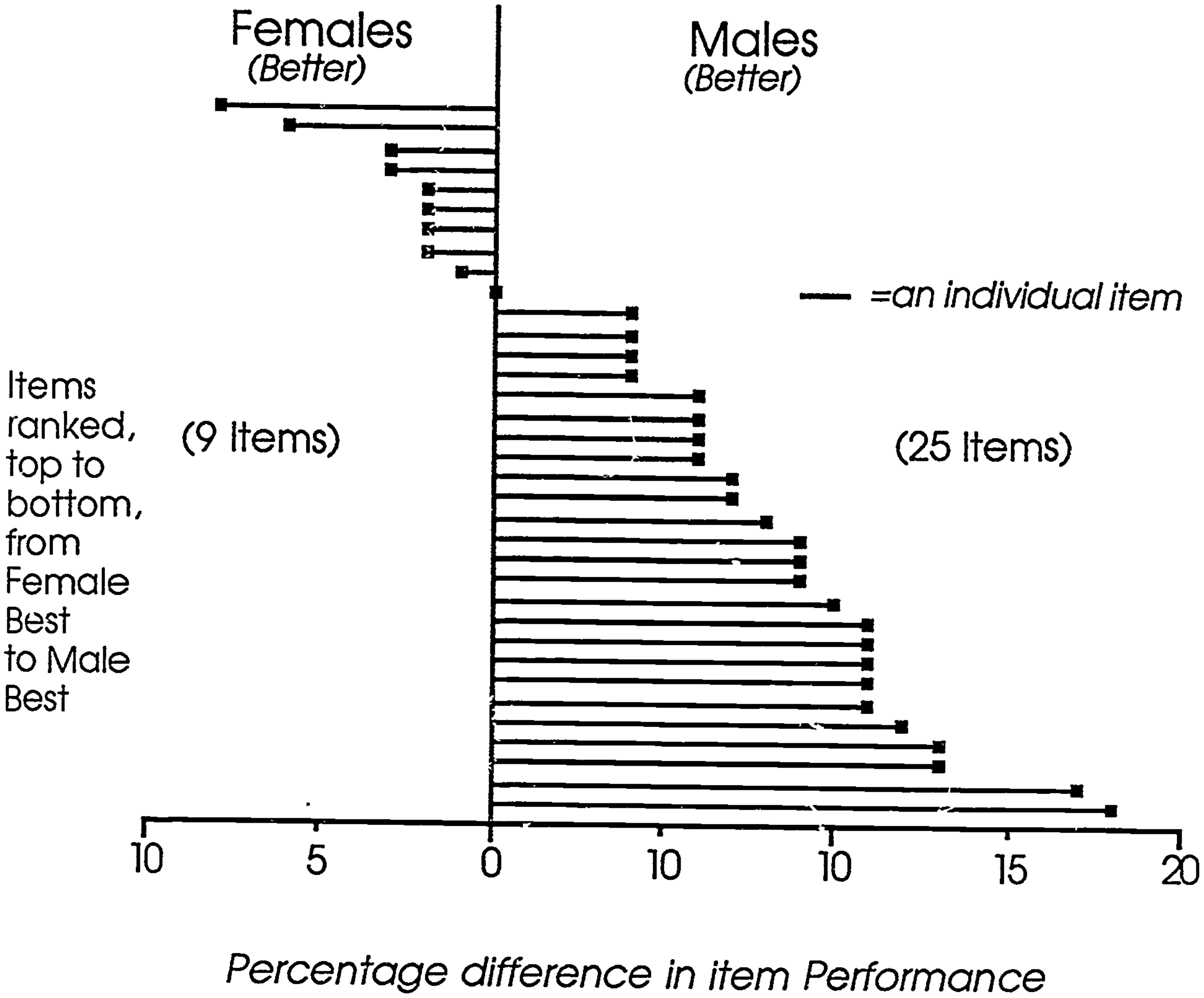
Male

1. In an experiment with a certain plant, the photosynthetic rate per unit of leaf area was measured at different light intensities. The experiment was repeated at three different temperatures, 5° C, 15° C and 25° C. An adequate supply of carbon dioxide was maintained throughout the experiments. The graph shows the results. On the basis of the data given in the graph, what factor or factors determine the photosynthetic rate in light intensities of more than 40,000 lux?

2. What adaptation characteristics would one probably find in desert plants?

3. In a population of 1000 fruit flies, the percentage of gene pairs were: TT = 15 percent Tt = 51 percent tt = 34 percent. If the fruit flies were free to breed normally, and if nothing happened to disturb the "gene pool", what would be the approximate percentage of tt two generations later?

Figure 13: Ontario Chemistry (Pop. 3).
Items on Which Males and Females Did Best and by How Much



Stems for the Top 3 Multiple Choice Items

Female

1. The atom $^{30}_{15}$ is an isotope of:

2. One kind of stainless steel contains approximately 13 percent chromium ond 1 percent nickel by mass; the rest is iron. Which of the following gives the closest approximation to the ratio of the number of chromium atoms to iron atoms in this stainless steel? The relative atomic mass of chromium = 52. The relative atomic mass of iron = 56.

3. An atom of a radioactive element first emits an alpha particle and then emits a beta particle. What happens to the nuclear charge?

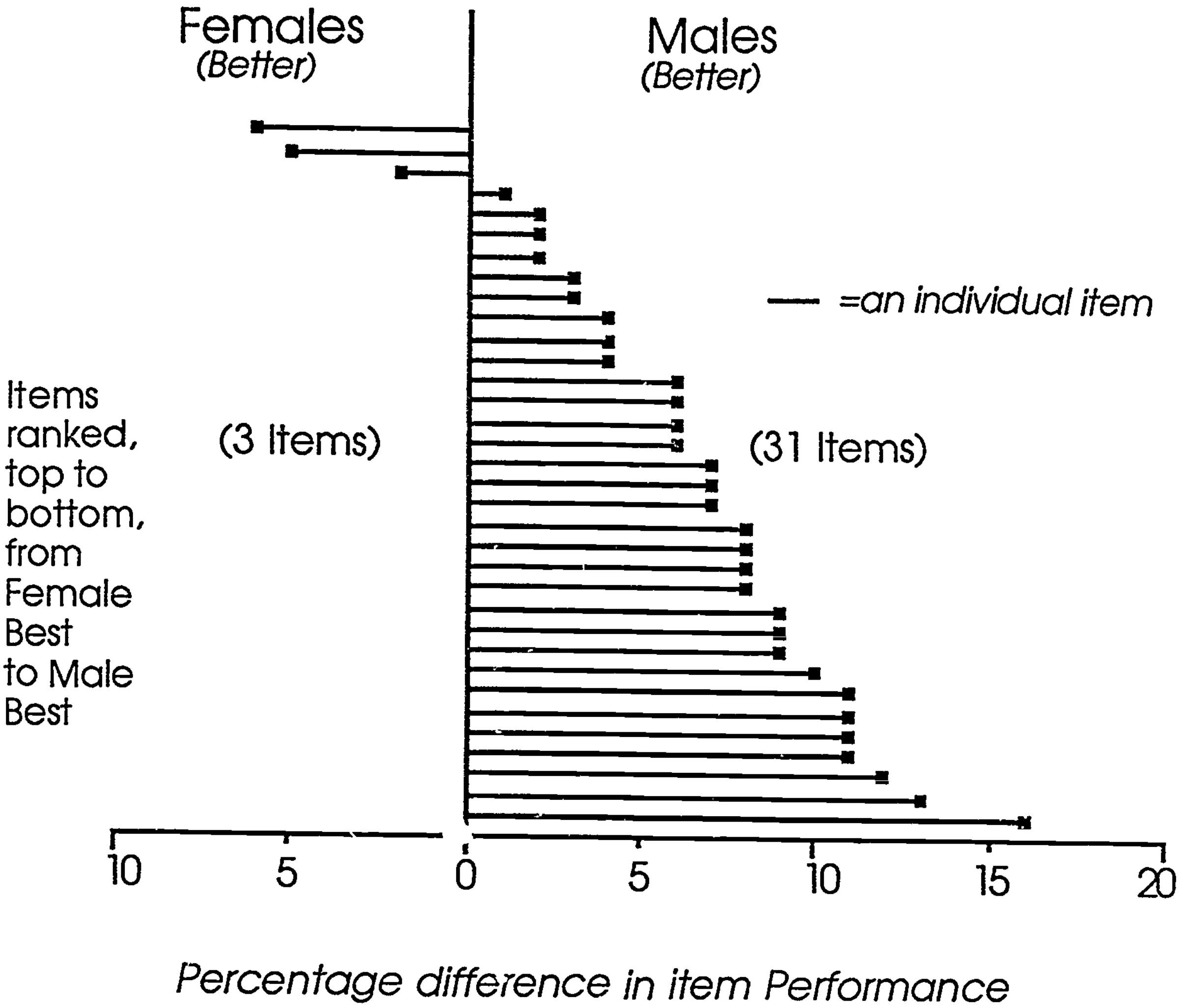
Male

1. In an experiment, 15.0 mL of 1.00 mol/L hydrochloric acid (HCl) neutralized 7.5 mL of a 1.00 mol/mL solution of an "unknown". Which one of the following is the "unknown"?

2. The solubility of a solid in water may be expressed as the number of grams of solid that can dissolve in 100 cm^3 of water. Which one of the following does the solubility depend on?

3. The following apparatus is set out on the laboratory bench: two vacuum (thermos) flasks, two thermometers, two measuring cylinders, a beaker containing 1.0 mol/L sodium hydroxide solution and a beaker containing 1.0 mol/L hydrochloric acid. Which one of the following procedures would give data from which you could most accurately obtain a value for the heat evolved in the neutralization of 1 mol of sodium hydroxide with hydrochloric acid?

Figure 14: Ontario Physics (Pop. 3).
Items on Which Males and Females Did Best and by How Much



Stems for the Top 3 Multiple Choice Items

Female

1. A car with a mass of 100 kg is moving with a constant velocity of 4.0 $m.s^{-1}$. What is its kinetic energy?

2. In the spectrum of the sun a continuous spectrum is crossed by many black lines (Fraunhofer lines). Which one of the following statements is correct?

3. Which one of the following particles may be best represented by the symbol $^{0}_{-1}X$?

Male

1. A ray of blue light passes through a stack of three blocks made of different materials. The blocks have parallel sides. The path of the beam is shown. In which of the three blocks is the velocity of blue light the greatest?

2. Car A, moving in a straight line at a constant velocity of 20$m.s^{-1}$, is initially 200m behind Car B moving in the same straight line at a constant velocity of 15$m.s^{-1}$. How far must Car A travel from this initial position before it catches up with Car B?

3. The energy from nuclear fission results from:

3.7.5. Male versus Female Science Achievement Differences: What Should We Do about Them?

The consistent success of males over females throughout the curriculum is graphically seen in the bar charts and line graphs. What is surprising to some of us is how early these differences are evident. It would be interesting to trace these differences back through the grades and to see where, and under what conditions, they first emerged. Do science achievement differences show up in Grade 1? Are they evident before students arrive in school? And, most important of all, why are they there? It would take a far more sophisticated study than ours to sort out the answers. Is it possible that boys are simply more interested in science than girls? We do have a little data on this point, which is reported later, but what we have is inconclusive. Besides, the "interest" question only "begs the question". We have only to ask "Why should there be interest differences?" to see the point.

The three general sorts of answers we may give to the basic question of why these gender differences exist are "genetic" (nature: 'boys are different than girls'), "environmental" (nurture: 'boys are taught to be boys and girls to be girls and anything in between is sissy or tomboy') and "educational" (nature x nurture: 'the schools have done this to our children'). The last answer, of course, is nothing more than a mix of the first two but it is worth pointing out. Parents and society are forever asking schools to do things that are quite against children's nature (e.g., sit still and listen all day) and they often ask the schools to nurture children in ways that are different from how they nurture in their personal lives (e.g., be in an environment that is overtly judgemental all day long, every day, throughout all the years of formal schooling). In other words, why blame the schools when we do not know what causes the differences and when, in society, we often lead our lives quite differently from the way we ask that schools treat our children?

Our own culture limits our ability to sort out the "genetic", "environmental" and "educational" differences between boys and girls. We are faced with the fact that our culture itself is not neutral in the way it presents male and female concepts of gender. Our ideas of achievement too are restricted by the kinds of knowledge and "ways of knowing" which are socially valued and tested. The difference in boys and girls' achievement may simply reflect the differences in the way society has valued particular ways of knowing over others rather than demonstrating significant differences between boys and girls in their ability to comprehend and think about subject matter. Following this line of reasoning Gilligan (1977), in her article "In a Different Voice" talks about different social and ethical voices that are used by individuals in society. This point of view is also reflected in the different "ways of thinking and knowing" that Belenky, Clinchy, Goldberger, and Tarule (1986) talk about in their book *Women's Ways of Knowing*. These people are trying to draw our attention to fundamentally different ways we teachers, researchers and policy makers may think about the apparently simple question of achievement. Though differences in achievement may have a genetic base, these same differences may be telling us something about the way we value different cognitive styles and ways of knowing as a society, rather than measuring the ability of the children tested.

Furthermore, these possibilities interact with cultural environment. I am reminded of Donna Deyhle's work in New Mexico (1986) where she worked with Navajo and Anglo schools in one school board and found different cultural attitudes between the two groups. The attitudes studied had a direct bearing on the question of achievement. Anglo students brought an attitude of personal accomplishment to school to which the traditional testing and achievement environment of school was ideally suited. The Navajo students brought an attitude of collective achievement in which individual accomplishment was devalued. The testing and achievement practices of the school were at odds with the Navajo students' sense of values surrounding performance. Now, I ask the reader an easy question: "Who do you think did better on the New Mexico school tests?" And I ask a hard question. "Should the curriculum and the Navajo students be squeezed, pushed and shoved to raise the Navajo achievement to match that of the Anglos?" Frankly,

taking the long and broad view I am glad I do not have to answer this question for New Mexico. What we do know is that the testing program *favours* one class of students over another. Isn't this quite possibly the case with males and females in Ontario science studies? The educational moral of this research on "voices", "ways of knowing" and "culture" it seems is that policy makers should take a long, long look before they make like Professor Henry Higgins in My Fair Lady ("Why can't a woman be more like a man?") and leap into curriculum efforts to reduce differences in science achievement between males and females.

Chapter 4
STUDENT ATTITUDES AND THEIR RELATIONSHIP TO ACHIEVEMENT

Most of us tend to think that attitudes cause achievement. In the work place, in day-to-day life, and in school we are forever counselling others, and ourselves, to change our attitudes for the better with the idea that this will make us do better. "Put on a happy smile" and "whistle while you work" are everywhere achievement maxims. But are good attitudes the cause of higher achievement? Or are they, rather, the product of high achievement? After all, when we do well we are inclined to have a happy face spontaneously rather than having to put it on. Raphael and Wahlstrom, in their analysis of IEA/SISS data (forthcoming) raise this question and appear to side with those that say they do not know. In their view the literature does not give a compelling answer to the question of whether or not attitudes are the cause of, or caused by, achievement. Readers, therefore, of our discussion of attitudes to science, must carry these questions in mind. Where we find good attitudes we are pleased to have them. But we do not know what difference they make. In some cases we do find positive relationships with achievement. It is always nice to notice good attitudes and good achievement varying together. But as Raphael and Wahlstrom remind us, when this happy occurrence takes place, we can do little other than enjoy it.

Still, notwithstanding what the research may show about the relationship of achievement to attitude, most of us care about attitude all by itself quite apart from achievement. If our children like science, care about it and think it makes a difference in their lives then that is important to us whether or not they are doing well in science. It is not everything. But it is something. For many of us it is the biggest part. Good attitudes are usually the first priority we have for our children. Achievement tends to be second best in our hopes.

We can do no more than present a few highlights in this report. This is due in part because of limitation of space and in part because of the limited number of analytic refinements possible. Many of the words written about achievement studies are made possible by the seemingly endless ways in which variables may be related to show interesting variation, one variable with another. But, in general, for the IEA/SISS attitude results variation is low compared to achievement variation. That is, students right across the country tend to be more alike in their attitudes, as determined in the IEA/SISS, than they are in their achievement. So there are analytic limitations to what we can do with their co-variation.

4.1. Do Students Like School? Do They Like Science?

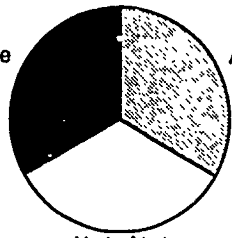
Students were asked a number of questions to find out whether they like school and a lesser number to find out if they like science. Raphael and Wahlstrom dealt with these items as sub-tests and worked with a composite score from several items. Let us, instead, look at a few specific items. Students were given statements and asked to agree or disagree. For example, one Grade 5 item reads:

I find school interesting. *Agree ( )* *Uncertain ( )* *Disagree ( )*

Items were asked the same way in Grade 9 but for the senior secondary items "strongly agree" and "strongly disagree" responses were added. For purposes of this booklet we collapsed the two agree and two disagree responses.

In this section results are presented graphically using pie charts. In order to avoid cluttering the charts with labels the following legend is presented as a model for all subsequent pie charts.

Pie Chart Key



Let us examine the results of the example statement and of two others. The three are:

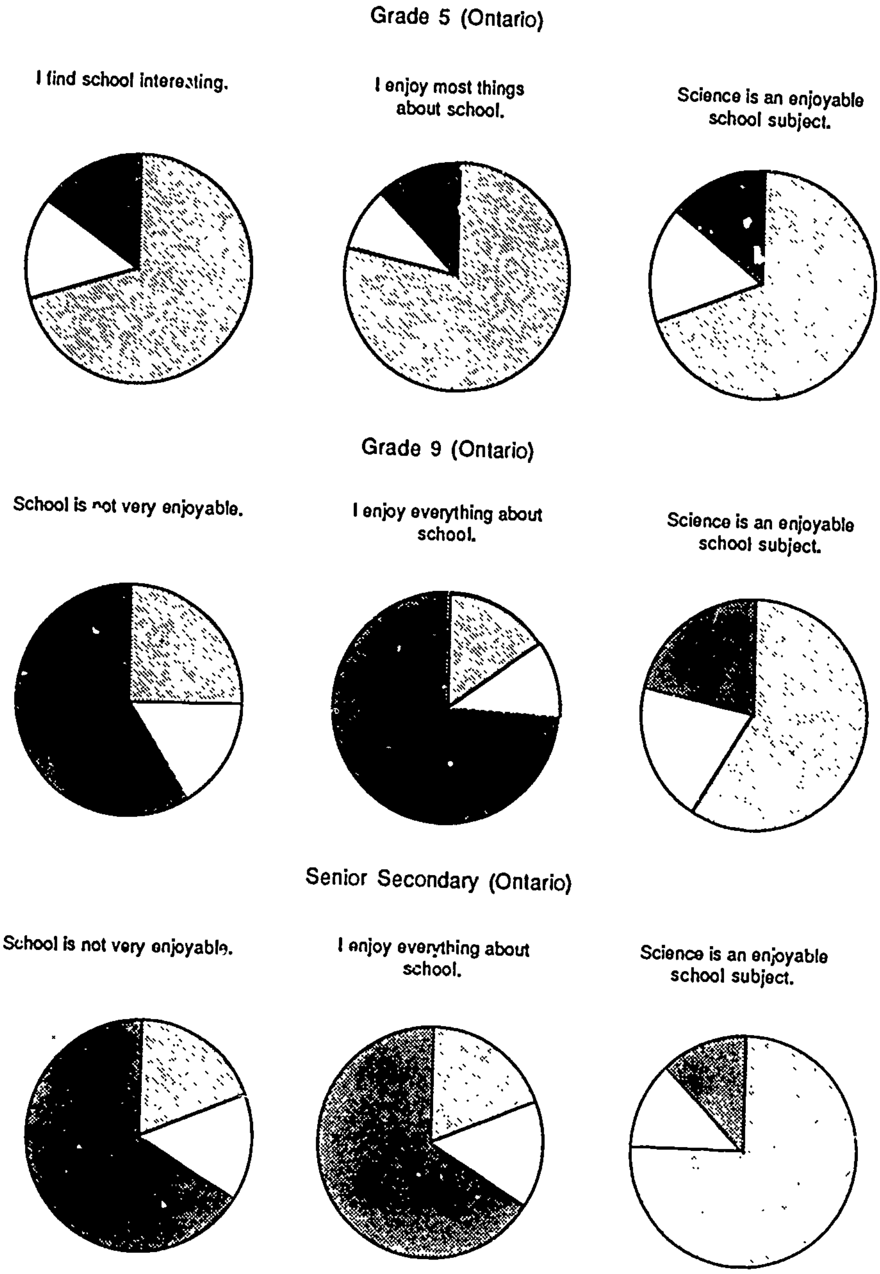
- *I find school interesting.*
- *I enjoy most things about school.*
- *Science is an enjoyable school subject.*

Seventy percent of the Ontario students in Grade 5 agreed with the first statement and a whopping 79 percent agreed with the second (Pie Chart Set 1). If our sample is an indication, a higher percentage of students like school in Ontario than do those in either the highest and lowest achieving provinces. Ontario, readers will recall, is not the highest achieving province in science at Grade 5. But the fact that students like school, notwithstanding their comparatively poor achievement, is encouraging. Not only that, but Ontario students overwhelmingly (81 percent) say that they *"want as much education as they can get"*. Curiously, on this item the lowest achieving province had by far the best student attitude, with 90 percent of students saying they wanted as much education as they could get. Ontario comes out below the national average on this point.

Ontario Grade 5 students' generally positive attitude to school shows up, as well, in their attitude to science, which 69 percent of them said they liked. Ontario students' attitude to science outshines lower (62 percent) and higher (57 percent) achieving provinces and is slightly over the national average. Still, students' attitude to science is significantly poorer than their overall attitude to school.

There is a down side to these figures, however, that gives us pause. Fifteen percent of Ontario Grade 5 students say they do not find school interesting and 12 percent disagree with the statement that they enjoy most things about school. Fourteen percent disagree that science is an enjoyable school subject. By comparison with high- and low-achieving provinces in the country, Ontario does comparatively well. A rather incredible 22 percent of students in the high-achieving province disagree with the statement that they enjoy science. Our Ontario sensibilities should not be dulled by these figures. Percentages turn into individuals and it is individual students, John, Mary, Bill and Susan, who do not like school and who do not like science. Think of it. Given that there were 117,327 Ontario children enrolled in school at Grade 5 when we did our study, this means that 17,599 children did not find school interesting and 16,426 children did not like science. That is a tragedy even if the averages in comparison with other provinces are good.

Let us take another item, *"I am bored most of the time in school"* (Pie Chart Set 2). Twenty-one percent of Ontario Grade 5 students agree with that statement. That is over one fifth of all Grade 5

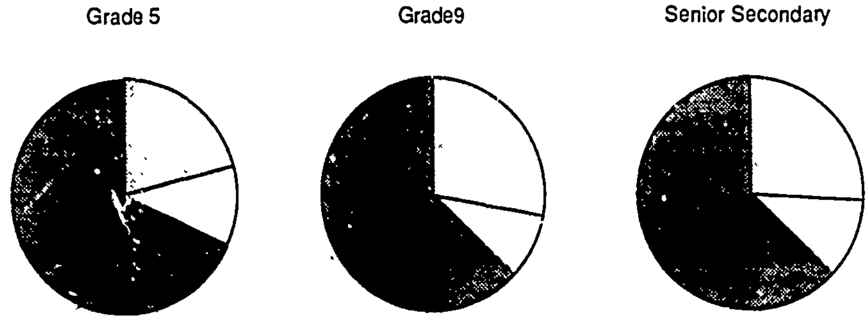


Pie Chart Set 1

children in Ontario schools. Approximately 25,000 Grade 5 children sitting in school are bored with it. That is a spectacular figure. But there is also a bright side. Another fifth of the school population actually agree with the statement, *"The most enjoyable part of my life is the time I spend at school"* (Pie Chart Set 2). Most of us, I suppose, would be glad to hear this. But I feel ambivalent about such a claim. We must wonder what kind of home and community life such students have. Do we want a society in which significant numbers of students are bored in school? Of course not. But do we want a society in which significant numbers of students are happiest when they are in school? I am not so sure. On the assumption that one of the main reasons students are personally connected to school is because of social relations with peers, we may not worry too greatly at the fact that so many say it is their favourite place to be. Still, if I had to choose, I would rather have a Grade 5 child of my own happy at home first and foremost.

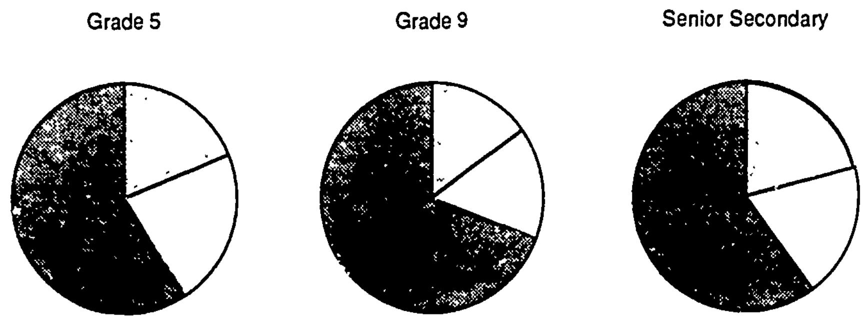
What happens to students' attitudes to school and to science between Grade 5 and Grade 9 (Pie Chart Set 1)? Since the questions asked at different levels were not identical, we cannot answer this exactly. But we can get a fairly good idea by looking at three comparable items:

I am bored most of the time in school (Ontario).



Pie Chart Set 2

The most enjoyable part of my life is the time I spend at school (Ontario).



- *School is not very enjoyable.*
- *I enjoy everything about school.*
- *Science is an enjoyable school subject.*

Generally speaking, there is a sharp drop in Ontario students' attitudes to school from Grade 5 to Grade 9. Only 59 percent of the Ontario students disagreed with the statement that school is not very enjoyable and 74 percent disagreed with the statement that they enjoy everything about school. The word "everything" is a poor one, however, and we must be reasonably suspicious of the results on that item. The advantage Ontario holds over the high- and low-achieving provinces in attitude at Grade 5 holds up. Roughly 10 percent fewer students in the lower achieving province and 7 percent fewer students in the higher achieving province disagree with this statement. So, like the rest of the country, Ontario students enjoy school less in Grade 9 than they did in Grade 5. But Ontario appears to be doing a better job of maintaining student interest in school than other provinces.

The number of students who agree with these statements, however, borders on the frightening. Exactly one quarter of all Ontario Grade 9 students agree that school is not very enjoyable and only 15 percent say they enjoy everything about school. A very large number of these students report being *"bored most of the time in school"* (Pie Chart Set 2), 28 percent all told in Ontario. Remember, these are not only abstract averages. They represent your child and mine, and, given the Grade 9 enrolment of 145,566 students when we did our study, 40,756 of our neighbours as well (on the assumption of one child per family in Grade 9). For the lowest achieving province the results are disastrous, with 38 percent of their students agreeing that school is not very enjoyable. Again, fewer students report being bored in Ontario than do students in low- and high-achieving provinces, although the gap is closed between Ontario and the high-achieving province compared to overall attitude at school.

The percentage of students who say, *"The most enjoyable part of my life is the time I spend at school"* (Pie Chart Set 2), holds fairly firm from Grade 5 to Grade 9, with 15 percent of the Grade 9 students in Ontario agreeing with the statement. Almost as large a percentage of students in the low-achieving provinces agree. It would be interesting to know the degree to which the highly positive attitude of specific children at Grade 5 is stable over the years. Are these the same children or different ones who think school is the best part of life in Grade 9?

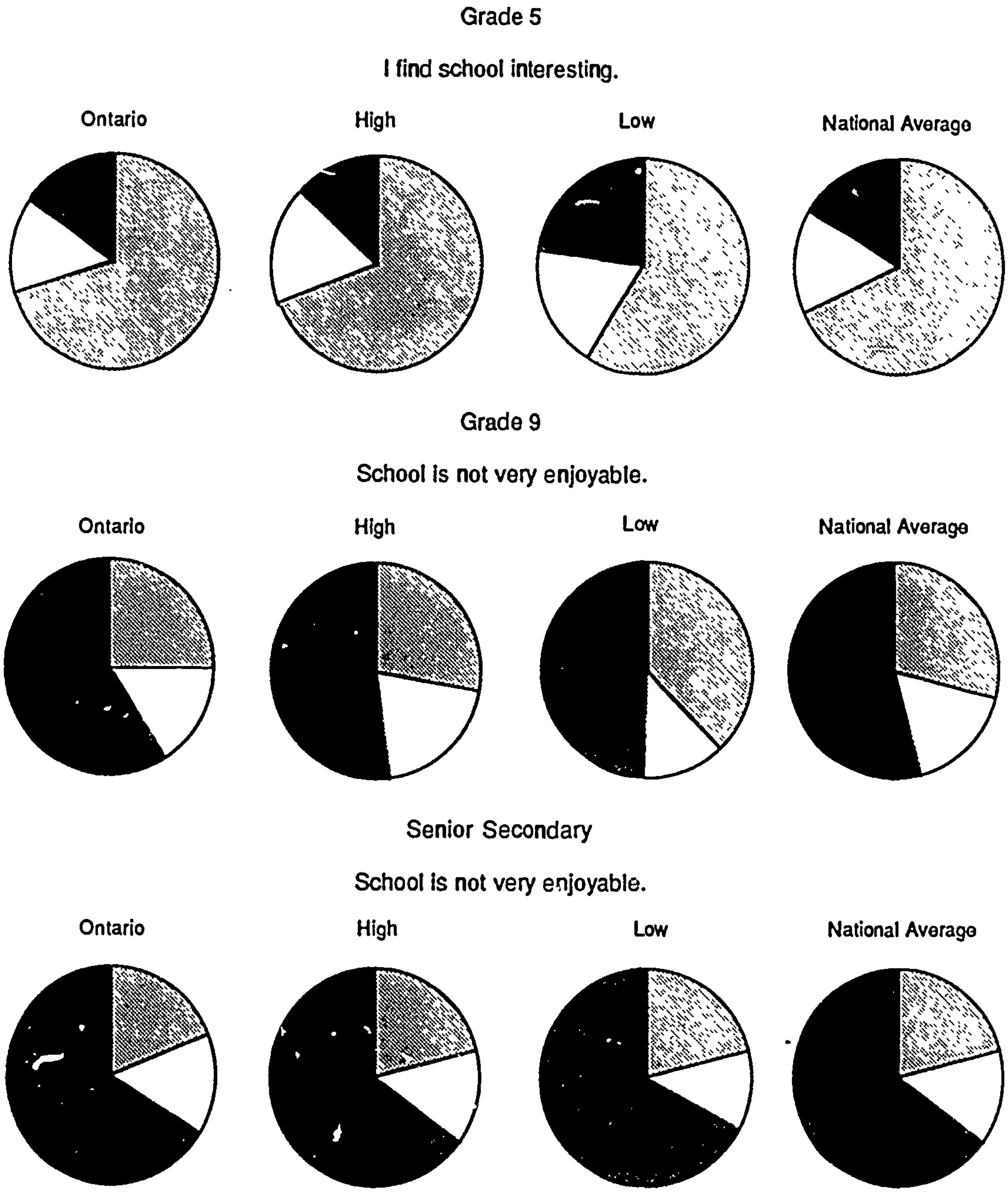
The drop in positive attitude to science from Grade 5 to Grade 9 is roughly the same in Ontario as it is for the overall drop in attitude to school. Fifty-nine percent of Ontario Grade 9s report that *"science is an enjoyable school subject"* (Pie Chart Set 1), and about 3 percent more say that *"science taught at school is interesting"*. On the negative side of the ledger, just over one fifth of the children disagree that science is an enjoyable school subject. It is also worth noting that close to 20 percent of the students report that they are "uncertain" on this matter. Part of this uncertainty may reflect the fact that some of the students are simply not being taught science.

When we get into the upper secondary school, Population 3, our results are complicated by the fact that we treated biology, chemistry and physics as separate school populations. As a result, we have three times as many numbers to deal with. The questions were quite similar for Population 3 as for Population 2 (Grade 9), and so direct comparisons are more easily made (Pie Chart Sets 1 and 2).

More senior secondary students than Grade 9 Ontario students (66 percent vs 59 percent) disagreed with the statement that school is not very enjoyable, and a larger percentage disagreed with the statement that they *"generally dislike school work"* (64 percent vs 59 percent). Overall, then the drop in attitude towards school noted between Grade 5 and Grade 9 has been halted, even turned upwards, in Ontario. A larger percentage even report that they enjoy everything about school than did students at Grade 9 (19 percent vs 15 percent). There is a drop of two percentage points in the students that say they are *"bored most of the time in school"* (28 percent vs 26 percent) and an increase in 3 percent of the students who say that *"the most enjoyable part of their lives is their time spent in school"* (18 percent vs 21 percent).

Cheering as they are, these figures are nothing to have a celebration about. *"Boredom"* in over a quarter of the secondary school science students is still serious. It is encouraging that the sharp dip from Grade 5 to Grade 9 is not continued throughout the high school years. We must remember, however, that Ontario, is a highly selected population since many of the students tested were in Grade 13, and most were in an academic route. A very large number of children have left school by this time and are not accounted for in this attitude increase. Had those school leavers been sampled, or had students in the general level program been tested, we might have expected a different picture. Looked at this way, we may well wonder whether the apparent slight rise in attitude masks, instead, an overall rejection of schooling. Still, Ontario ranks about the same as high- and low-achieving provinces (Pie Chart Set 3). Oddly, a slightly higher percentage of students in low-achieving provinces said they *"enjoyed everything about school"*, and more of them said they disagreed with the statement that they *"generally dislike their school work"*. The provinces with the highest secondary school achievement had, in fact, the highest percentage of students saying they were *"bored in school"*. On the assumption, however, that the tested Ontario population is more highly selected academically than in other provinces, we have to wonder at the effects of schooling in Ontario on both achievement and attitude.

By and large, there are only small differences in overall attitude to school between students registered in biology, chemistry and physics. Still, students registered in biology have a slightly poorer attitude to school. A higher percentage of them find *school not very enjoyable* and fewer of them *enjoy everything about school.* A slightly smaller percentage say that the *most enjoyable part of their life is the time they spend in school.* Differences are in the neighbourhood of 2 percent when compared with



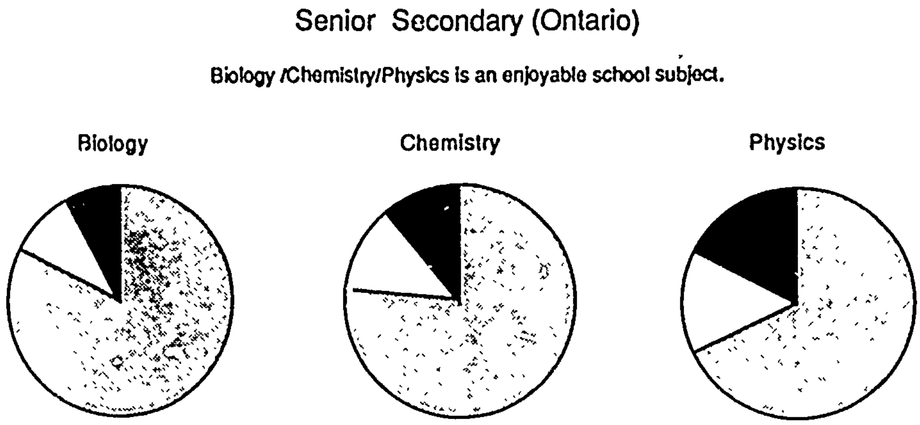
Pie Chart Set 3

chemistry and physics. On the other hand, a larger percentage of physics students report being *bored* in school. Also, on the question of whether students *enjoy everything about school,* about 4 percent more students in biology compared to physics and chemistry (59 percent vs 65 percent) said they enjoyed everything about school. In short, this is a somewhat mixed picture.

When we try to find out if students like science at the senior secondary level, the picture becomes more complicated because of the subject-based definition of our population (Pie Chart Set 4). Students registered in each subject were asked if they liked that subject. There are sharp differences in how much students like the science subjects in which they are registered. Eighty-three percent of Ontario biology students say that *"biology is an enjoyable school subject"*, whereas 77 percent and 68 percent of chemistry and physics students, respectively, say the same about their subjects. It is not only, therefore, that students self-select in each of these subjects and therefore like them. It is also the case that after they have self-selected, there are significant differences in how well students like their chosen subjects, biology coming off the top and physics considerably lower. Exactly the same thing shows up when the item is

stated in a slightly different way: *"The biology (chemistry, physics) taught at school is interesting."* Here the relevant percentages for biology, chemistry and physics, respectively, are 85 percent, 78 percent, and 70 percent.

Pie Chart Set 4



It may be that these differences in attitudes to science reflect the difficulties students encounter with those subjects once enrolled. When the question of whether or not the subject is difficult was asked (*"Biology/chemistry/physics is a difficult subject"*), the figures appear in exactly inverse order (41 percent, 51 percent, and 70 percent). In short, almost twice as many physics students say their subject is difficult than do biology students say of their subject. It is almost as if large numbers of the physics students think their subject is unteachable. When Ontario students were asked to agree or disagree with the statement, *"If properly taught, almost all students could learn biology (chemistry, physics)"*, 84 percent of biology students agreed whereas only 70 percent of chemistry students and 60 percent of physics students agreed. It would appear from this that more students get in over their heads in physics than is the case in chemistry and biology. Turned around, and looked at from the point of view of general education, biology as taught appears to be a better place to be for students than physics or chemistry. This does not mean that physics and chemistry could not be taught in different ways. But our results show that students find physics hard and do not think teaching it differently would make much difference.

4.2. Is Science Valuable in Students' Eyes?

There are those who worry that, with the threat of nuclear war and the running record of environmental disasters reported in the popular media, an anti-science spirit might be awakening in students. Students were, therefore, asked questions in an attempt to ferret out the social and personal values they saw in science. Several of our questions were answered in ways that are interesting in themselves. The general picture that emerges is that, quite apart from how well students are doing in science and what their attitudes towards it are, students think science is socially important. No advertising campaigns are needed to promote the idea of science as a socially useful endeavour in Ontario schools. Our students are already convinced.

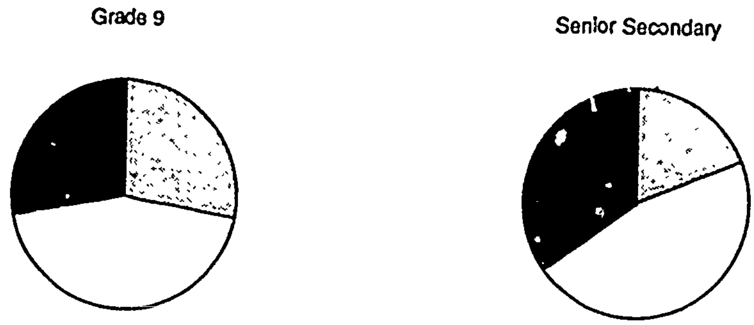
Let us look at some of the results. Several questions were asked of all students at all levels. Beyond that, the Grade 9 and senior secondary questions were very similar with related, but not identically worded, questions at the Grade 5 level.

Ontario senior secondary students appear to have a more upbeat view of the future than do students in Grade 9. When asked to agree or disagree with the statement, *"In the next five years things in Canada will probably get worse"* (Pie Chart Set 5), fewer students agreed and more students disagreed in Grade 9

as compared to senior secondary students. Grade 9 students were almost equally divided between agreeing, disagreeing and being uncertain. Still, there was a fair amount of uncertainty on this matter by secondary students, with over 40 percent of the students being in doubt. Biology students are just a touch more skeptical of the future than either physics or chemistry students. In general, there is a hint in these results that students are in a state of uncertainty about the future. Far more sophisticated research on this question appears to be warranted.

In the next five years things in Canada will probably get worse (Ontario).

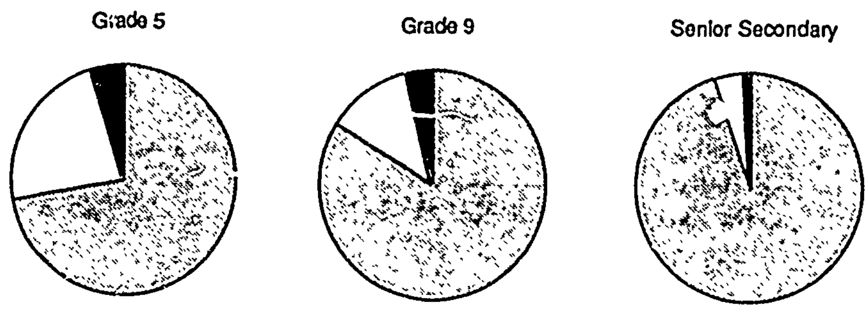
Pie Chart Set 5



On the question of how useful science is, however, there is virtually no doubt in the students' minds. In responding to the statement, *"Science is very important for a country's development"* (Pie Chart Set 6), there was a sharp increase in positive response from Grade 5 to Grade 9 and another increase from Grade 9 to senior secondary. Seventy-two percent of Grade 9 students agreed with the statement and only 5 percent disagreed. In Grade 9, 84 percent agreed, with only 4 percent disagreeing, and at the senior secondary level 95 percent of the students agreed and only 1 percent disagreed. This item, in fact, was the item on which there was most agreement by all students, not only in Ontario but right across the country. The scientific community may well feel that science has a low priority socially, as represented in national research policies. But if secondary school science students were funding those programs, the scientists would appear to have little difficulty.

Science is very important for a country's development (Ontario).

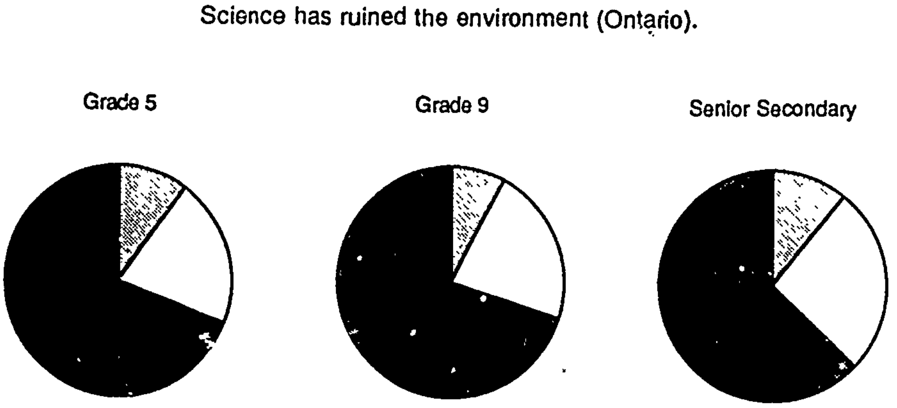
Pie Chart Set 6



Still, when we asked students' their view on whether or not *"the government should spend more money on scientific research"*, far fewer students agreed than those who had seen science as useful to the country: just a little over half of the senior secondary students, a little over a third of Grade 9 students and about a fifth of Grade 5 students. This was true even though 85 percent of the students in the senior secondary school thought that money spent on science was well worth spending. Students appeared to have a strong feeling that they would personally benefit from science, and approximately 90 percent of the senior secondary school students think that scientific inventions will improve their standard of living.

These positive views of the value of science were found when we probed on the negative side of the ledger as well. Less than 5 percent of senior secondary school students think that *"science has done more harm than good"*, a drop of four percentage points from Grade 5. There seems to be a little more ambivalence on the relationship of science to environmental quality at the senior secondary level, with an increase of three percentage points (8 percent to 11 percent) from Grade 9 to senior secondary school agreeing with the statement, *"Science has ruined the environment"* (Pie Chart Set 7). There was a corresponding drop in the number of students who disagreed with that statement (70 percent to 63 percent). Actually there is a large percentage of students at the senior secondary school level who are uncertain on this matter. These findings suggest that students are increasingly aware of the relations between science, quality of life, quality of the environment and technology. These findings seem to mimic societal ambivalence on the losses and gains of an increasingly scientific and technologically based society.

Pie Chart Set 7



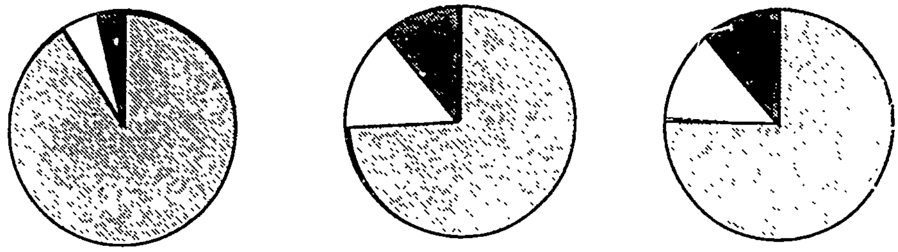
This view is more or less borne out in a series of questions we asked on the relation of science to *anxiety in society, complexity in the world, interpersonal tensions*, and *world problems*. Roughly 20 to 40 percent of senior secondary school students variously put the blame on science for difficulties in these areas. For example, 43 percent of the senior secondary school students agreed with the statement, *"Scientific inventions have increased tensions between people"*. This is a increase of two percentage points from Grade 9.

For many of these science-in-society issues, biology students tend to respond only slightly differently than chemistry and physics students. For instance, 36 percent of biology students agree that *"science and technology are the cause of many of the world's problems"* compared with 33 percent and 28 percent in chemistry and physics, respectively. In all cases, physics students seem to be the least sensitive to, and pessimistic about, social issues, biology students the most.

On the question of relevance to everyday life there is, however, a dramatic difference between biology and other science students at the senior secondary level. Ninety-one percent of biology students agree that *"biology is relevant to everyday life"* (Pie Chart Set 8), whereas only 74 percent of chemistry students and 76 percent of physics students agree that their subject is relevant to everyday life. These figures are considerably higher than in Grade 9 where only 61 percent of the students see science as relevant to everyday life. The implication of these subject differences, it appears, is that the physics and chemistry teachers ought to consult the biology teachers on the question of how to make science more personally and socially relevant.

Biology/Chemistry/Physics is relevant to everyday life (Ontario).
Senior Secondary

Pie Chart Set 8



4.3. Male and Female Attitudes tc School and to Science

There is little doubt that females tend to have a more positive attitude towards school than do males. This shows up early in schooling, as seen in two Grade 5 items, *"I find school interesting"* (Pie Chart Set 9) and *"I enjoy most things about school"*. Seventeen percent and 16 percent, respectively, more females than males agreed with the two statements. Five percent fewer females report being *"bored with school"*, and 7 percent more of the females say that *"the most enjoyable part of their life is the time spent at school"*. But even though females have a better overall attitude to school, 4 percent fewer of them said that *"science is an enjoyable school subject"*.

At Grade 9 the attitude differences between males and females remain. Fourteen percent more boys than girls agreed with the statement, *"School is not very enjoyable"* (Pie Chart Set 9). Four percent more females than males said they *"enjoyed everything about school"*, and 11 percent more males said they were *"bored in school"*. As in Grade 5, more males (4 percent more) enjoy science than do females.

The differences in male and female attitudes to school remain more or less firm at the senior secondary school level. More males than females say that *"school is not very enjoyable"* (Pie Chart Set 9), and more females than males say that they *"enjoy everything about school"*. More males than females report being *"bored with school"*.

There are some differences, although not striking, between the three senior secondary subjects (Pie Chart Set 10). The largest difference between males and females tends to be in biology. The differences between males and females on the question of whether or not *"biology (chemistry, physics) is enjoyable"* is about 5 percent greater in biology than it is in chemistry and physics. And there is the least difference between males and females on the question of whether they *"enjoy everything about school"*. The percentage difference holds about the same for each subject on the question of whether or not students are *"bored in school"*.

When we turn to students' attitudes to science subjects, however, the results are quite striking. Eighty-five percent of the female biology students, 5 percent more than male biology students, report liking biology. Females even like chemistry more than do males by a slight margin (78 percent vs 76 percent). It is only in physics that the female attitude to science drops sharply. Only 57 percent of the females report enjoying physics whereas 72 percent of the males enjoy physics. From this it would appear that the majority of students, male and female, enjoy biology, about three quarters of them enjoy chemistry and slightly over half of the females enjoy physics. The fact that most of the students in these courses are there because they chose to be makes these figures a little worrisome. Another way of looking at it is that 85 percent of the females taking biology enjoy it whereas only 57 percent of the females taking physics enjoy that subject.

Grade 5

Males Females

I find school interesting (Ontario).

Grade 9

School is not very enjoyable (Ontario).

Pie Chart Set 9

Senior Secondary

School is not very enjoyable (Ontario).

On balance, then, senior secondary female attitudes to science are more positive than are male attitudes. We only know this, of course, for students who are registered in a science course. Physics is the only subject where the boys' attitudes are more positive, and by a wide margin.

When we compare female and male attitudes towards the value of science to themselves and to society generally, we find that although differences are not large, females tend to be somewhat more dubious of the merits of science. However, the Grade 5 picture is quite mixed. For instance, more males than females say that *"scientific discoveries make our lives easier"*. Yet more males than females agree that *"science has ruined the environment"*, while saying that *"science will help to make the world a better place for the future"*. But more males than females also say that *"scientific discoveries do more harm than good"*. Perhaps all this means is that this kind of question is ambiguous and confusing to Grade 5 students.

The picture is still confused at the Grade 9 level but at the senior secondary level matters become a little clearer. More males than females think *"science is useful for solving problems of everyday life"* (Pie

Senior Secondary (Ontario)

Males

Females

Biology is an enjoyable school subject.

Chemistry is an enjoyable school subject.

Pie Chart Set 10

Physics is an enjoyable school subject.

Chart Set 11). There is a rather large difference (14 percent) in favour of males who believe that *"people who understand science are better off in society"*. More males than females believe that *"the government should spend more money on scientific research"*. Although more females than males think that *"scientific inventions have made the world too complex"*, more males than females believe that *"scientific inventions have increased tensions between people"*. Perhaps the largest difference of all between males and females at the senior secondary level is in the attitude to the future. A significantly larger number of males than females think that *"science will help to make the world a better place in the future"* (Pie Chart Set 11). Still, the picture on male and female attitudes to the place of science in society and their personal lives is ambiguous in our results. Even though males had high hopes for the future, a slightly larger percentage of them believed that *"science had ruined the environment"*.

Senior Secondary (Ontario)

Males Females

Science is useful for solving problems of everyday life.

Pie Chart Set 11

Science will help to make the world a better place in the future.

Chapter 5

TWO CONDITIONS FOR TEACHING SCIENCE: LABORATORIES AND CURRICULUM DECISION MAKING

Chapter 5 briefly discusses two matters often considered to be of considerable importance to the teaching and learning of science. The first consideration is the use of laboratories and the second is the question of who has decision-making control over the curriculum.

5.1. How Well Equipped with Science Laboratories and Laboratory Technicians Are Our schools?

Science is a subject that cannot properly be learned only from books. Traditionally, in higher education, teaching laboratories are commonplace and laboratories have also found an important niche in school-level teaching. We, therefore wondered how well equipped the schools were with special rooms for science and asked in the School Questionnaire:

> *How many rooms or laboratories in your school are specially equipped for science teaching and/or student practical work?*

Results for all three populations (Grades 5, 9, and 13) in Ontario and in high- and low-achieving provinces as well as the national average are presented in Table 9.

Table 9: Average Number of Laboratories per School by Province and Population

	National	Ontario	High	Low
Population 1	0.4	0.2	1.0	0.7
Population 2	3.5	5.4	2.2	1.8
Population 3	4.7	5.7	5.3	2.4

Because laboratories take a great deal of organization, care and preparation time, we also wondered how extensive the laboratory technician support staff was for science teachers. On the assumption that this question would not make sense at the Grade 5 level, we addressed the following question only to Grade 9 and senior secondary schools:

> *How many laboratory assistants or technicians (full-time equivalent) are there in your school?*

Results are presented in two different ways. Table 10 presents the average number of laboratory technicians per school and Table 11 shows the percentage of schools which have laboratory technicians.

Table 10: Average Number of Laboratory Technicians/Assistants per School by Province and Population

	National	Ontario	High	Low
Population 2	0.10	0.10	0.04	0.0
Population 3	0.19	0.13	0.55	0.7

Table 11: Percentage of Schools with Laboratory Technicians/Assistants by Province and Population

	National %	Ontario %	High %	Low %
Population 2	9.8	8.3	17.7	0.0
Population 3	16.2	9.2	51.1	2.4

It appears that Ontario schools are poorly equipped with laboratories and science classrooms at the elementary level. Roughly one in five Ontario Grade 5 schools report having laboratories (0.2 laboratories per school), a figure which is half the national average. Five times as many schools in the highest performing province have science laboratories in their Grade 5 schools. The Ontario picture is made worse when we consider that Ontario schools are larger than the national average by almost 10 students per school.

This comparatively dismal situation is rectified in the secondary schools, however, where Ontario has by far the best record at Grade 9 and is above the national average in the senior secondary school. Our possible enthusiasm at the apparent advantage of Ontario schools in laboratory space at Grade 9 and senior secondary must be tempered by our observation that Ontario schools are larger at these two population levels. Table 12, which shows the average number of students per laboratory, suggests that the main Ontario deficit is at the senior secondary level where there are 5.6 more students per laboratory than the national average and a whopping 30.2 more students per laboratory than the highest achieving province.

In general, however, laboratory space in intermediate and secondary schools does not seem to be a problem in Ontario, at least in the schools we sampled. We even have some evidence at the Grade 9 and secondary level to suggest show that Ontario schools make more efficient use of their school laboratories. When principals responded to a question asking what percentage of the time their laboratories were in use for science teaching, Ontario came out ahead nationally and also in comparison to high-achieving provinces. But, as in other comparisons, Ontario compared poorly on laboratory usage at the elementary level.

The Ontario picture with respect to science teachers' assistants in the form of laboratory technicians is, however, bleak. On average, there are only 0.1 technicians per Ontario Grade 9 school and, of the schools reporting, only roughly 1 in 12 (8.2 percent) had a technician (Tables 11 and 12). Although these figures are right around the national average, they will seem far too low to those who know what it takes to properly teach science. Ontario schools are not much better off at the senior secondary level although the

Table 12: Average Number of Students per Laboratory by Province and Population

	National	Ontario	High	Low
Population 2	201.1	187.3	219.0	234.3
Population 3	178.3	183.9	153.7	255.4

national averages have almost doubled and the high-performing provinces have tripled. There are, therefore, two concerns at the senior secondary level. Too many schools (91 percent) have no laboratory technicians *and* Ontario compares poorly with the national average and especially poorly with the highest-performing provinces.

5.2. Who Takes Responsibility for the Science Curriculum?

One of the perennial battles in school systems is over the degree of decentralization that ought to be permitted in curriculum matters. This is not only a matter of power politics among the various interested parties but is also an ideological and empirical matter. Those who have no direct stake in the matter can, and do, take both sides on the issue. Some with a strong sense of localism and individualization argue that richer educational possibilities are tied to the decentralization of authority. Others argue that to ensure common and high achievement on socially specified goals a strong central authority is required. Tomkins' book *A Common Countenance* (1986) traces the ups and downs on this matter in Canadian schools since the time of Ryerson and Ryerson's organization of the Ontario school system.

From the point of view of what actually happens in schools, both parties to the dispute are probably correct in their own terms. If a specific achievement goal is set for, say, a province then clearly the best way to achieve that goal is to ensure that all provincial classrooms teach towards the goal. Furthermore, the more that variations in local and classroom adaptations take away from direct instruction on the goal the less likelihood that the goal will everywhere be achieved at a high level. From this point of view the centralists are correct. But to the degree that single-minded pursuit of a goal reduces the freedom of local areas and specific teachers to adapt instruction to the lives of students, the curriculum will be less rich in its offerings. From this point of view the decentralists are correct. Actual situations are, of course, a mix of both points of view.

It is impossible, therefore, to settle the argument on achievement grounds alone. Suppose, for example, that a highly centralized system shows high achievement. The centralists may say, "I told you so", and the decentralists may say, "See how authoritarian, barren and unconcerned with children is the curriculum." Or suppose, as seems to be somewhat the case in Ontario, based on our results, a decentralized system shows large numbers of children with positive attitudes to school and comparatively weak achievement. The decentralists may cheer and the centralists may cry for more central control. Clearly, the matter is not settled on the "facts" of achievement. This is not the way to tell if one system is "better" than another.

I do not propose to argue the matter one way or the other for this manuscript. But we did collect some interesting material to show that there is considerable variation on this matter in Canada and that Ontario contributes significantly to the national variation. We asked school principals the following questions in the School Questionnaire:

Which persons or groups of persons are responsible for making decisions in the following matters?

1. determining content of science courses at individual grade levels

2. choosing textbooks for science students

Key
A. a central authority
B. a school board or school district
C. the school principal
D. a teacher or group of teachers from the school
E. some other person or groups of persons
F. does not apply to this school

Responses E and F were virtually unused by principals in responding and were dropped from the analysis. Results for the first question are presented in Figures 15, 16, and 17 and for the second question in Figures 18, 19, and 20.

For Canada as a whole there is a perceived steady increase in the influence of a central authority across the grades. Roughly half of the Canadian principals of Grade 5 schools think a central authority is important and by senior secondary school the figure is close to 90 percent. The Ontario pattern is strikingly different from the national picture. Low (81.8 percent) and high (97.9 percent) province respondents gave an eight to nine times higher rating to a central authority than did Ontario (11.3 percent) respondents. Moreover, although there is a fairly large increase in perceived central authority in Ontario from Grade 5 to Grade 9 schools (11.3 percent to 60.0 percent) and a small rise again at the senior secondary level (to 68.9 percent), the difference between Ontario and the other provinces remains in the neighbourhood of 30 to 40 percent. For other provinces there does not appear to be much variation in who decides on the science curriculum. Central authorities do. But not so in Ontario.

Corresponding to the strengthening of the central authority across the grades, there is a drop across the grades in all three other groups responsible for curriculum content. School boards, which play a reasonably large role nationally (28.6 percent) in Grade 5 schools drop to 3 percent in the senior secondary schools. Teachers also drop although not so precipitously (from 18.6 percent to 12.7 percent). The figures for the principals are interesting because they suggest that right across the country principals have little say on curriculum content. The idea of the "principal as curriculum leader" seems pretty much to be dead in Canada. In fact, it is only in Ontario, which is far more decentralized than the rest of the country according to this item, that the principal is seen to play a curriculum role.

The comparison between Ontario and the rest of the country is striking when the influence of teachers, boards and principals is examined. The principal and school board play no role whatsoever (according to our figures) in determining the content of science courses in high- and low-achieving provinces. Ontario school boards (62.9 percent) are clearly of considerable importance to elementary science content, unlike the case in the rest of Canada. Teachers and principals, but mainly teachers (21 percent and 4.8 percent) also play a significant role in Ontario's elementary schools. Their curriculum role actually appears to increase slightly in secondary schools. unlike the case in high and low-achieving provinces. In fact, in Grade 9 schools neither teachers nor principals have any role in determining science content, in either high- or low-achieving provinces. The national figures for principals and teachers are, therefore, made up primarily of Ontario's contribution.

Ontario is seen to be most like other provinces by respondents at the senior secondary level, although it remains very much more decentralized compared to low- and high-achieving provinces. Slightly over a quarter of the Ontario respondents think teachers primarily and principals secondarily (23.5 percent and 1 8 percent, respectively) determine science content. The equivalent figures for high- and low-achieving provinces are less than 3 percent.

Figure 15: Responsibility for Determining Content of Science Courses in Population 1 Schools

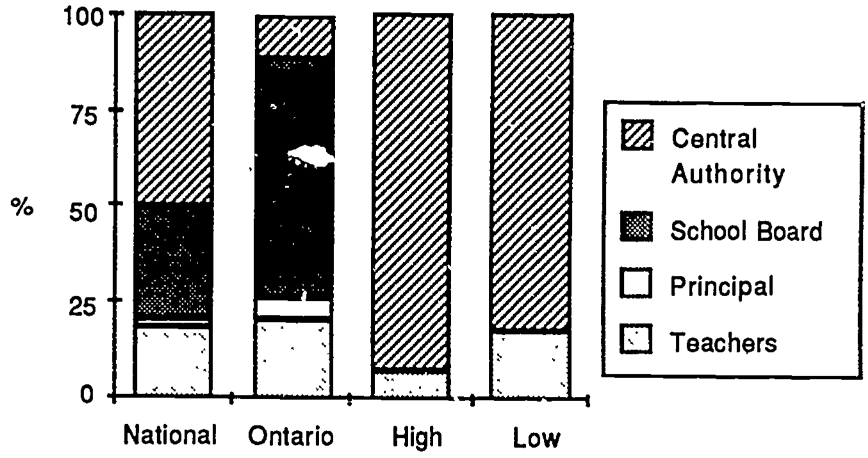


Figure 16: Responsibility for Determining Content of Science Courses in Population 2 Schools

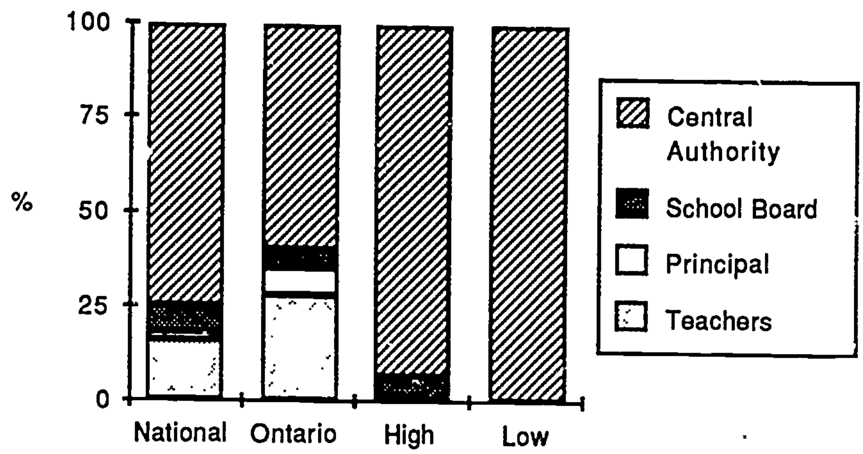


Figure 17: Responsibility for Determining Content of Science Courses in Population 3 Schools

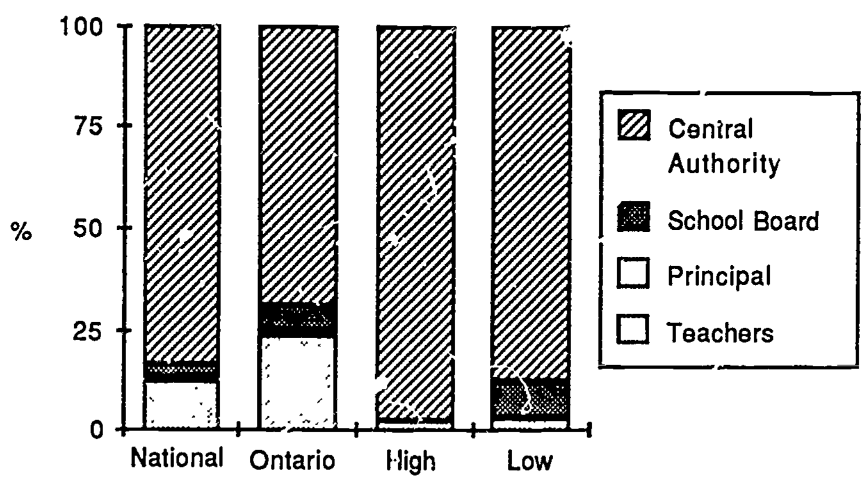


Figure 18: Responsibility for Choosing Science Textbooks in Population 1 Schools

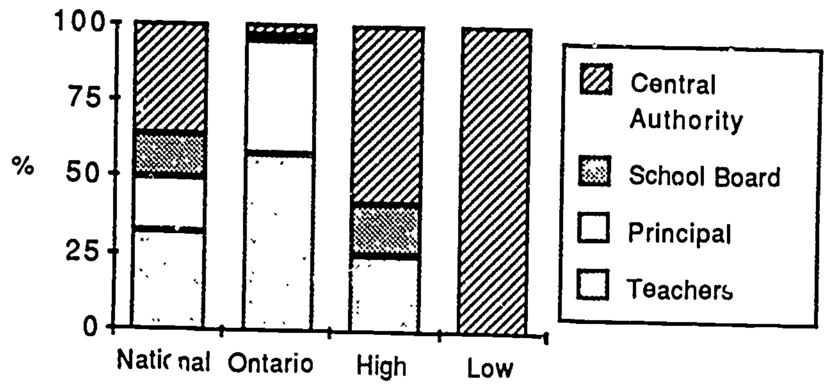


Figure 19: Responsibility for Choosing Science Textbooks in Population 2 Schools

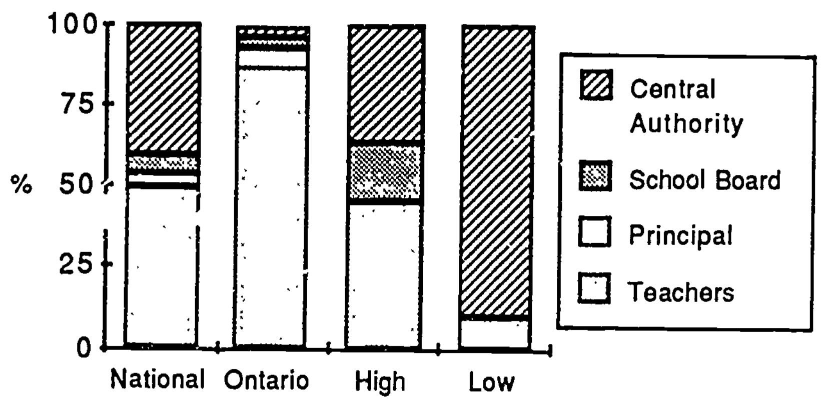
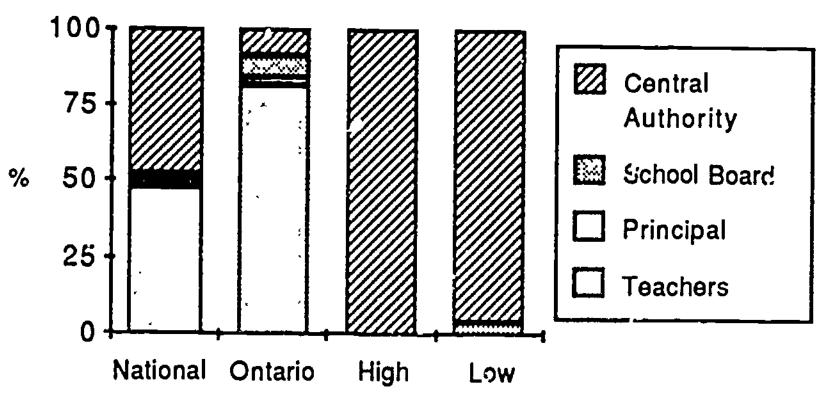


Figure 20: Responsibility for Choosing Science Textbooks in Population 3 Schools



The data on who chooses science textbooks are almost a mirror image of the selection of content question. These are, of course, closely related questions, as intended. For many people, especially those in the senior secondary level in highly centralized settings, the two questions may even be identical. That is, the choice of science textbooks by a central authority specifies the content of science courses. In these situations, books and courses actually amount to the same thing.

Still, there are some interesting differences between the results on the two questions. Respondents from the low-achieving provinces uniformly rate the central authority as important in the choice of textbooks. But, the high-achieving province assigns a far larger role in the choice of textbooks to the school board in Grade 5 and Grade 9 schools than it does both in the senior secondary level schools *and* in comparison with the low-achieving province. Ontario, again, is the provincial anomaly since teachers and principals are seen as by far (over 90 percent) the most important agent in the choice of textbooks at all levels (over 90 percent in Grades 5 and 9 schools and close to 85 percent in senior secondary level schools). Teachers and principals appear to have no role whatsoever in this matter in most other provinces.

Returning to the original discussion of decentralization versus centralization we see that there are extreme differences around the country. Readers are reminded of our discussion in the first part of this report on the comparative analysis of curriculum policy documents and of the degree of specificity and prescriptiveness contained therein Ontario is by far the most decentralized as determined by our two questions. We notice that *both* high- and low-achieving provinces at all levels are far more centralized than is Ontario with respect to curriculum. In short, even when achievement on specific science goals (the IEA/SISS tests) is used as a criterion it is impossible to decide whether decentralization is best. Those with a predilection for centralization will point to the fact that the highest performing provinces are strongly centralized, leaving little in the way of curriculum decisions to teachers, principals and school boards. Decentralists can say exactly the same thing for low-achieving provinces. Accordingly, it appears that other matters are more important in sorting out the question of how best to administer the schools.

Chapter 6

THE ONTARIO SCIENCE EDUCATION REPORT CARD: A SUMMARY

This report is written in a condensed form. Findings are presented in a straightforward way, mostly without discussion of associated, complex interacting factors and almost entirely without recourse to relevant research literature. As a result, each chapter is essentially a non-technical summary of findings. Consequently, this final chapter is a summary of a summary. It is presented as a set of highlights without comment. Where possible, relevant comparisons are made with high- and low-achieving provinces in the country. Readers may, therefore, read this chapter as a provincial report card. Just as a student's report card in June sums up in a page or two a year's worth of student performance so, too, this chapter sums up what is known from SISS on Ontario's science education performance.

As in any report card, readers must be reminded of the context. The report card is based on Ontario's participation in the Canadian component of the Second International Science Study of the International Association for the Evaluation of Educational Achievement. The main contribution of this study is to point the way towards a school-based, evidentially supported, method of curriculum reform. The study is limited in several ways, the most important of which is that classroom teaching and learning data are absent. To this extent, the report card is also limited.

6.1. The Teaching Force

- Over one third of all Canadian educators are found in Ontario. The number of educators in Ontario is 70 times that of the smallest province.

- Secondary school teachers have stronger educational backgrounds than do elementary teachers. Roughly 65 percent of elementary school teachers have university degrees, some 20 percent less than those in the secondary schools.

- The educational backgrounds of Ontario Grade 5 teachers show extremes. Twice as many Ontario Grade 5 teachers have no science courses in their background as compared to those in the Western and Eastern provinces. But far more Grade 5 teachers in Ontario than in the East and the West have a science specialization.

- At Grade 9 over a quarter of the teachers have no science background although close to a half have a science major.

- At Grade 12 Ontario has the largest number of teachers (8 percent) with no science background although 86 percent have a science major.

6.2. Science Teacher Professionalism

- Ontario science teachers are a professionally oriented group. There are nine provincial and three national science teachers' organizations to which they may belong.

- The most important of these is the Science Teachers' Association of Ontario which plays an increasingly active role in Ontario science education policy.

6.3. Research in Science Education

- Ontario has a poor record of research in science education, given the number of faculty members devoted to science education throughout Ontario universities.

6.4. Policy Documents

- There is very little similarity from province to province in the kind of documents used to express science goals and content.

- The specific goals of science are relatively common across the country but the specific content outlined to achieve those goals varies considerably.

- The degree of commonality across the country in the science curriculum is low in the elementary school and comparatively high in the secondary school.

- Biology shows the least commonality at all levels across the country.

- The Eastern provinces tend to prescribe a larger proportion of the science curriculum than do the Western provinces. Ontario shows the most variation, with a low level of prescription in biology and a high level of prescription in chemistry.

6.5. Student Enrolments

- In Ontario, biology and chemistry are selected by about equal numbers of students. Physics is the least popular secondary school science subject.

- Ontario has the best balance in enrollment among the sciences at the secondary school level of all provinces.

- On a percentage basis, Ontario appears to attract a larger percentage of its students into science than do other provinces.

6.6. Student Achievement

- Ontario achievement is below the national average in Grade 5 and Grade 9 and slightly above the national average at the senior secondary level. Compared to the highest achieving province in Canada, Ontario is about 4 percentage points lower in Grade 5 and over 5 percent lower in Grade 9. At the senior secondary level, Ontario is a little less than 2 percent below the highest performing provinces.

- Ontario was the highest achieving province in one instance: chemistry, in senior secondary school. In grades 5 and 9, and senior secondary school physics and biology the highest achievement scores were recorded by students in one of the Western provinces.

- Ontario did not have the lowest achievement score for any of our tests. An Eastern province was lowest in all but one case, senior secondary school chemistry, where one of the Western provinces had the lowest average achievement score.

- Biology students outscore chemistry and physics students across the country. The spread is slightly larger in Ontario than it is in either the highest or lowest performing province or the national average. Also, the difference between the physics score and biology score is greatest in Ontario, meaning that in comparison with other subjects physics students are doing poorly in Ontario compared to the rest of the country.

- Ontario is the top-performing province in senior secondary chemistry. But at Grade 5, Ontario's chemistry sub-score is comparatively poor.

6.7. Male and Female Achievement

- Males outscore females on average in Ontario and across the country. The differences, however, are not as large as some might have imagined.

- Females outscored males at only two points throughout the Canadian science curriculum: in Grade 5 in the lowest achieving province and at the senior secondary level in biology in an average of all provinces.

- There is a greater Ontario difference between the sexes at Grade 5 than for either the highest or lowest performing province.

- The greatest discrepancy between the sexes in Ontario secondary schools is in physics.

6.8. Student Attitudes to School and to Science

- Student attitudes to school are high in Grade 5, drop sharply at Grade 9 and then more or less hold firm for Ontario students.

- Ontario student attitudes are, in general, more positive than they are in the rest of Canada although Ontario comes out below the national average on the question of how much education students want.

- Student attitudes to science subjects are not as positive as are their overall attitudes to school.

- Over one fifth of the Grade 5 students are bored in school; the percentage increases at Grade 9.

- Another fifth of the students find school the most enjoyable part of their life.

- There are sharp differences in how much students like the Senior Secondary Science science subjects in which they are registered, with biology enjoyed the most and physics the least.

6.9. Valuing Science

- Generally speaking, students have an overwhelmingly positive attitude to the value of science to society and to themselves.

- Biology students at the senior secondary school level think biology is more relevant to everyday life than do chemistry and physics students.

6.10. Male and Female Attitudes to School and to Science

- Females have a consistently more positive attitudes to school than do males at all levels.
- The average male attitude to science is more positive than is the average female attitude. However, this is made up entirely of large differences in favour of males in physics. Females actually show more positive attitudes to science in biology and chemistry.

6.11. Science Laboratories

- Ontario is poorly equipped with science laboratories in Grade 5. Five times as many schools in the highest performing Canadian province have science laboratories in their Grade 5 schools.
- Ontario's laboratory situation has been rectified at Grade 9 and in the senior secondary school.
- Ontario has a poor record with respect to laboratory technicians for teaching science. Ontario is at about the national mean in this respect at Grade 9, but by the senior secondary school Ontario compares poorly with the top-performing provinces and with the national average.

6.12. Curriculum Decision Making

- Ontario is unlike any other Canadian province in the degree to which curriculum decision making is decentralized. Both the high and low achieving provinces are more centralized than is Ontario. It is only in Ontario that teachers and school principals have a significant role to play. Boards of education also play a more important science curriculum role in Ontario than in any other province.

6.13. A General Summary

- Ontario students have positive attitudes to school and to science but their achievement is not as high as might be expected of the richest province in Canada. Ontario shows innovativeness in curriculum decision making and exhibits more confidence in its local personnel than do other provinces.

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Appendix A
TABLES

Table 13: Major Moments in Ontario Science and Science Education: 1945-1983[1]

<u>1945</u> 10 rehab centres for war vets Cmsn. on Planning Construction & Equipment est. Educational guidance introduced in Gr. 9 Larger school units est.	<u>1946</u> Prov. Institutes: Hamilton-Textiles, Haileybury-Mining, Lakehead-General, Polytech - Toronto. Teachers' summer schools reopened. Teachers' College (TC) for tech teachers moved to Toronto	<u>1947</u> Composite secondary schools est.
<u>1948</u> Lakehead Tech. promoted to Junior College Prov. Inst. in Toronto reopened as Ryerson P.I.	<u>1949</u> Hope Cmsn., <u>Interim Report</u> on teacher training. HS entrance exams abolished Intermediate Div. est. with special curriculum Porter Plan	<u>1950</u> Recommended text system Legislative grants reorganized Hope Cmsn. Final Report Decentralized curr. planning. Local cmte's est. for Inter. Div. curriculum & student transfer to sec. schools Toronto Dist. Sc. Teachers' Assoc. (TDSTA) founded Sc. Teachers' Assoc. of Ont. (STAO) meetings in schools
<u>1953</u> Normal schools renamed Teachers' Colleges (TC) Emergency Training plan for elem. teachers initiated Hamilton & London TC moved to university campus TV opened in Toronto	<u>1954</u> New power plant opened at Niagara Falls D of E Act	<u>1955</u> Emergency training for sec. teachers initiated
<u>1957</u> VTT agreement signed Prof. Dev. Branch added to D of E to do inservice prog's	<u>1958</u> Gr. 9 science survey	<u>1959</u> York U opened First large-scale nuclear power plant opened in Bruce Co. McMaster U. opened atomic reactor

[1] The Major Moments are abstracted from *Science Education in Canada: Policies, Priorities, & Perceptions* (Connelly, Crocker, & Kass, 1985). For a similar list for all provinces and for an annotation of each item, readers should turn to the abstracting source.

1960 Laurentian U est. as non-denominational bilingual univ. Lakehead TC opened STAO affiliated with U.S. National Sc. Teachers' Assoc. (NSTA) TDSTA opposed to new Inter. Div. Sc. guidelines Sec. teacher training at London, Kingston	1961 TTA signed Experimental guid. or Inter. Sc. Emergency training for elem. teachers phased out	1962 Reorganized Prog. of Studies for Sec. Sch.: 3 branches of study Report on training sec. teachers New guidelines for Agric. Sc. Windsor TC opened
1963 Design for learning Ont. Curr. Inst est.: sc. curr. revised at senior level 1963-1969 Report on training of sec. teachers (Pullan) Sudbury TC opened	1964 STAO moved conventions to commercial site	1965 19 Colleges of Applied Arts & Technology (CAAT) est. Ont. Inst. for Studies in Ed. (OISE) est. Review of teacher ed. begun London TC renamed Althouse C & affiliated with Univ. of Western Ont. (UWO) St. Catharines TC opened
1966 STAO constitution revised to include elem. teachers Report on training of elem. teachers (MacLeod) Teacher Ed. Br. reorganized; Elem. & Sec. Ed. integrated Elem. curr. revised. Report of Grade 13 cmte. Administrative reorganization of school boards	1967 Sec. Schools & Boards of Ed. Act STAO joint convention with NSTA	1968 Gr. 13 exams phased out. Living & Learning French language sec. schools est. Kingston TC renamed McArthur C & affiliated with Queen's U Innovations in Sec. School Planning piloted Environmental Sc. guides Agric. Sc. Teachers' Assoc. renamed Environmental Sc. Teachers' Assoc. (ESTAO)
1969 Teacher training prog. reorganized to integrate TC's into universities. Guides for Space & Tech and Man, Sc. & Tech courses Fall conference for STAO Emergency Sec. teacher training phased out Report of Cmsn. on Post-sec. Ed. (Wright)	1970 New plan for sec. schools est.; credit system introduced, areas of study introduced, individual timetabling, new HS1 circular. Can. Assoc. of Sc. Teachers (CAST)-STAO Conference Council of Outdoor Educators (COEO) est. York U. Fac. of Ed. est.	1971 Ontario's Educative Society D of E reorganized STAO reorganized on regional basis STAO Curr. Resources Cmte. formed; Resource Centre opened at McArthur Coll. Other STAO Cmte's formed.

1972 Intermediate Sc. (Interim) guide STAO presented brief to Cost of Ed. Cmsn. on teacher certification	**1973** First CHEM-ED Conference STAO Curr. Study Cmte. study on curr. design problems Envir. Sc. (Interim) guide	**1974** STAO withdrew from Ont. Ed. Assoc. (OEA)
1975 The Formative Years & Ed. in the Primary & Junior Divisions, (Circulars P1J1 & EPJD) STAO brief on senior biology curr. Metrication prog. initiated Minimum requirements for elem. teachers raised to B.A. or B.Ed.	**1976** Energy conservation project Man-Environment Impact Conference STAO published Senior Div Physics: A Core Curr. for Gr. 11 & 12 and Chemistry Core Topics booklet STAO survey of opinions and practices of sec. chem. teachers.	**1978** Intermediate Sc. guide STAO Cmte. on Elem. level sc. ESTAO study to develop new curr. guide Ont. Teacher's Certificate became sole cert. issued by prov. Interim Report of Cmsn. on Declining Enrolments (Jackson)
1979 Teacher Training Br. moved to Min. of Colleges & Universities; TC integration into univ. completed Energy Educators (EEO) est. Ont. Chapter of Amer. Assoc. of Physics Teachers (AAPT) est. STAO published Elements for elem. teachers STAO study of senior level biology Final CODE Report	**1980** Issues & Directions published goals of education in Ont.	**1981** Final Report, Sec. Ed. Review Project (SERP) Ont. Assess. Instrument Pool (OAIP) materials for Physics & Chemistry First Gr. 11 Physics competition STAO survey of Inter. sc. teachers
1982 Report on the Renewal of Sec. ERd. in Ont. (ROSE Report) Man-Environment Impact Conference Environmental Sc. guides prepared; then shelved	**1983** New regulations for sec. ed. in Ontario; circular OSIS replaced HS1 Sc. Curr. writing teams prepared new sc. guides for Inter. & Sen. levels Sc. in the Primary & Junior Div OAIP field tests of Physics & Chemistry test items	

Table 14: Distribution of Grade 5 Students by Province/Territory and Region[2]

Province Territory	Grade 5 enrolment -- all schools (Population cohort) Total	Male	Female	Included	Excluded	% Excluded
Northwest Territories	1 205	609	596	1 205	-	-
Yukon Territory	370	188	182	370	-	-
British Columbia	37 780	19 432	18 348	35 317	2 463	6.5
Alberta	33 985	17 327	16 658	32 974	1 011	3.0
Saskatchewan	15 808	8 109	7 699	15 119	689	4.4
Manitoba	16 236	8 339	7 897	14 678	1 558	9.6
WESTERN REGION	105 384 (29.9%)	54 004 (29.8%)	51 380 (29.9%)	99 663 (39.0%)	5 721 (5.9%)	
Ontario	121 365	61 842	59 523	117 327	4 038	3.3
Quebec	87 221	45 053	42 168	-	87 221	100
CENTRAL REGION	208 586 (59.1%)	106 895 (59.1%)	101 691 (59.1%)	117 327 (45.9%)	91 259 (93.7%)	43.8
Newfoundland	11 040	5 526	5 514	11 003	37	0.3
Nova Scotia	13 712	7 071	6 641	13 522	190	1.4
Prince Edward Island	2 024	1 086	938	2 014	10	0.5
New Brunswick	12 238	6 392	5 846	12 098	140	1.1
EASTERN REGION	39 014 (11.1%)	20 075 (11.1%)	18 939 (11.0%)	38 637 (15.1%)	377 (0.4%)	1.0
CANADA	352 984 (100%)	180 974 (100%)	172 010 (100%)	255 627 (100%)	97 357 (100%)	27.6%

Source: Statistics Canada. 1983-84 Elementary-Secondary Enrolment. Ottawa: Statistics Canada, 1985.

[2] From D. Jantzi & D. MacKeracher (1984), *Sampling and Administration Report.*

Table 15: Distribution of Grade 9 Students by Province/Territory and Region[3]

Province Territory	Grade 9 enrolment -- all schools (Population cohort) Total	Male	Female	Included	Excluded	% Excluded
Northwest Territories	594	274	320	594	-	-
Yukon Territory	368	191	177	368	-	-
British Columbia	42 416	21 488	20 928	40 117	2 299	5.4
Alberta	34 233	17 217	17 016	33 332	901	2.6
Saskatchewan	15 942	8 064	7 878	15 205	737	4.6
Manitoba	16 448	8 279	8 169	15 166	1 282	7.8
WESTERN REGION	110 001 (27.6%)	55 513 (27.3%)	54 488 (28.0%)	104 782 (36.1%)	5 219 (4.8%)	
Ontario	149 006	51 602	47 525	145 566	3 440	2.3
Quebec	99 127	51 602	47 525	-	99 127	100
CENTRAL REGION	248 133 (62.3%)	127 634 (62.8%)	120 499 (61.9%)	145 566 (50.2%)	102 567 (94.8%)	41.3
Newfoundland	11 607	5 744	5 863	11 568	39	0.3
Nova Scotia	14 185	7 172	7 013	13 965	220	1.6
Prince Edward Island	2 185	1 137	1 048	2 176	9	0.4
New Brunswick	12 068	6 190	5 878	11 975	93	0.8
EASTERN REGION	40 045 (10.1%)	20 243 (10.0%)	19 802 (10.2%)	39 684 (13.7%)	361 (0.3%)	0.9
CANADA	398 179 (100%)	203 390 (100%)	194 789 (100%)	290 032 (100%)	108 147 (100%)	27.2%

Source: Statistics Canada. 1983-84 Elementary-Secondary Enrolment. Ottawa: Statistics Canada, 1985.

[3]From D. Jantzi & D. MacKeracher (1984), *Sampling and Administration Report*.

Table 16: Distribution of Population 3 Students by Province/Territory and Region[4]

Province Territory	Final year Enrolment* -- all schools (Population cohort) Total	Male	Female	Included	Excluded	% Excluded
Northwest Territories	331	155	176	331	-	-
Yukon Territory	237	137	100	237	-	-
British Columbia	37 504	19 317	18 187	35 633	1 871	5.0
Alberta	33 844	17 626	16 218	32 948	896	2.7
Saskatchewan	14 606	7 268	7 338	13 841	765	4.6
Manitoba	16 513	8 333	8 180	15 329	1 184	7.2
WESTERN REGION	103 035 (33.5%)	52 836 (33.9%)	50 199 (33.1%)	98 319 (48.7%)	4 716 (4.5%)	4.6
Ontario (Grade 13)	72 044	37 985	34 059	69 234**	2 8 0	3.9
Quebec (Grade 11)	97 436	48 277	49 159	-	97 436	100
CENTRAL REGION	169 480 (55.2%)	86 262 (55.4%)	83 218 (55.0%)	69 234 (34.3%)	100 246 (95.2%)	59.2
Newfoundland	8 933	4 281	4 652	8 910	23	0.3
Nova Scotia	12 146	5 854	6 292	11 966	180	1.5
Prince Edward Island	2 074	963	1 111	2 074	-	-
New Brunswick	11 590	5 609	5 981	11 489	101	0.9
EASTERN REGION	34 743 (11.3%)	16 707 (10.7%)	18 036 (11.9%)	34 439 (17.1%)	304 (0.2%)	0.9
CANADA	307 258 (100%)	155 805 (100%)	151 453 (100%)	201 992 (100%)	105 266 (100%)	34.3%

* Enrolment in Grade 12 except as noted.

** Estimate. Students registered in Roman Catholic schools are reported by the Ontario Ministry of Education as "private" students in Grade 13.

Source: Statistics Canada. 1983-84 Elementary-Secondary Enrolment. Ottawa: Statistics Canada, 1985.

[4] From D. Jantzi & D. MacKerracher (1984), *Sampling and Administration Report*.

Table 17: Estimated Enrolment in Final Year Science Courses and Total Enrolment by Province/Territory and Region[5]

	Biology	Chemistry	Physics	Total
Territories	200	180	110	568
British Columbia	7 880	5 630	3 380	35 633
Alberta	14 210	14 550	8 120	32 948
Saskatchewan	9 790	7 010	5 990	13 841
Manitoba	5 120	4 680	3 390	15 329
WESTERN REGION	37 000	31 870	20 880	98 319
Ontario	33 140	33 130	28 100	69 234
Newfoundland	5 010	610	2 600	8 910
Nova Scotia	5 830	4 610	2 910	11 966
Prince Edward Island	1 020	690	460	2 074
New Brunswick	2 660	2 670	2 430	11 489
EASTERN REGION	14 520	9 580	8 460	34 439
CANADA	84 660	74 580	57 440	201 992

Sources of data: Statistics Canada. (1985). Elementary and secondary school enrolment, 1983-84. Catalogue 81-210. Ottawa: Supply and Services Canada.

Course enrolments for Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick are as reported to Robert K. Crocker, Memorial University of Newfoundland, by relevant departments of education.

Percentage enrolments for Manitoba, Saskatchewan and British Columbia and for female participation in Nova Scotia and Saskatchewan, derived from the draft report, Canadian secondary school enrolment in mathematics and science: A statistical report, prepared by Cicely Watson for the Science Council of Canada, March 1984.

Ontario Ministry of Education. (1984). Education statistics for 1983-84. Toronto: Ontario Ministry of Education.

Alberta Education. (1984). Annual report, 1983-84. Edmonton: Alberta Education.

[5] From D. Jantzi & D. MacKeracher (1984), *Sampling and Administration Report.*