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Mathematics and Science in Liberal Arts
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1. Summary

1.1 Abstract

This project investigates the attitudes of two successive cohorts (2000, 2001) of students in the Dawson College Liberal Arts program toward mathematics and science. The purpose is to determine whether their studies in Liberal Arts, in particular the conception of mathematics and science presented in Liberal Arts courses, affect the attitudes which they show at the time of their entry into the first semester of college studies. Our hypothesis is that the program approach used in the Liberal Arts Program, which emphasizes curricular integration of different disciplines, and of subject matter and abilities, improves the attitudes of students with respect to mathematics and science. To test this hypothesis, a series of questionnaires examines the students' relevant high school grades and averages, their initial attitudes, and their attitudes and relevant grades as they progress through their program of studies. The results show a marked difference between students' attitudes to mathematics as compared to science. In both subjects, between 1/6 and 1/3 of the responding students reported an improved attitude; while a majority of all cohorts showed no change or a more negative attitude.

1.2 Objectives and questions asked by the research

The objectives of the project are (1) to analyze the main components of students' attitudes; (2) to relate these to each other and to students' performance in the relevant courses; (3) to investigate to what extent students' attitudes may be changed by the way in which mathematics and science are presented to them and contextualized in the Liberal Arts program This project identifies student attitudes toward mathematics and science as falling into five categories: relative ease or difficulty, personal attitude, importance of teaching in determining attitude, importance of subject matter in determining attitude, current understanding of the aims and methods of the subject.

1.3 Methodology

After the initial collection of data on the students' performance in high school mathematics and science, three questionnaires were administered to each experimental cohort: the first questionnaire, in the first term, before the students' mathematics and science course; the second questionnaire, in the mid-term of their respective courses; and the third questionnaire, at the end of their courses. The researchers were also teaching the mathematics and science courses; however, the research protocol guaranteed that the initial data and all student responses were anonymous. The data was analyzed using standard statistical measures to detect whether any changes of attitude occurred.

2. Findings and Conclusions

2.1 Findings The main findings consist of: a portrait of each of the entering cohorts in respect of their high school records and attitudes towards mathematics and science; within each cohort the distribution of students' ratings, expressed quantitatively, of their attitudes to these subjects; a comparison, for each cohort, of students' attitudes from mid to end term in their respective mathematics and science course; and the difference in student attitudes towards mathematics as compared to science. A third cohort was included in the project for the purposes of mathematics alone.

2.2 Conclusions This study finds no marked pattern of general improvement in students' attitudes, except in the case of the 2000 cohort with respect to mathematics. However, some proportion of each cohort, ranging from 16.% to 35% of respondents, report more positive personal attitudes toward both mathematics and science. The data support the conclusion drawn from teachers' observations that these students view science as a vocation or a career whereas they consider mathematics a subject that may be useful in many fields including science. In all cohorts, students' grades in mathematics are highly correlated with their reported understanding of the subject, whereas in science there is no such correlation.

3. Introduction

3.1 The subject of research: In this project we have investigated the attitudes of two successive cohorts of students in the Dawson College Liberal Arts program toward mathematics and science. The purpose was to determine whether their studies in Liberal Arts, in particular the Liberal Arts mathematics and science courses, affected the attitudes which they showed at the time of their entry into the first semester of college studies. Our hypothesis was that the program approach used in the Liberal Arts Program, which emphasizes curricular integration of different disciplines and subject matter and abilities, improves the attitudes of students with respect to mathematics and science. To test this hypothesis, we examined (please see Methodology, below) the students' relevant high school grades and averages, their initial attitudes, and their attitudes and relevant grades as they progressed through their program of studies. We intended our investigation to bear upon the effectiveness of the program approach in the teaching of mathematics and the history and methodology of science in the Liberal Arts program at Dawson College. We confined 'effectiveness' to denote the extent to which Liberal Arts students' attitudes became more positive toward these two subjects in comparison to their initial attitudes. We hoped that our results would also permit us to draw conclusions about differences in student attitudes towards mathematics as compared to science (please see Conclusions, below).

3.2 Background: The teaching of mathematics and science presents an important issue for secondary and post-secondary schools, i.e. high schools, Cegeps[1], colleges and universities. There exists great difficulty in teaching these subjects successfully, as is shown by relatively high failure rates and by the negative attitudes of students with respect to these areas.[2] This problem is the more serious because of the importance of these fields, and persists despite the expenditure of resources to ensure that these subjects are taught well. A lack of understanding and skills in mathematics and science at the Cegep level can severely limit the university options and career choices of students.

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[1] E.g., "La place des mathématiques au collégial: mémoire présenté à L'honorable ministre, M. Claude Ryan ...". Centre de documentation collégiale, www.cdc.qc.ca: #709441.

[2] Lafortune, L. ***Dimensions affectives en mathématiques.*** Modulo, Mont Royal, Que. 1998; and ***Adultes, attitudes et apprentissage des mathématiques***. Cegep André Laurendeau, LaSalle, Que., 1990; Lamontagne, J. & Trahan, M. ***Recherche sur les échecs et abandons: rapport final.*** 1974: Centre de documentation collégiale #718854; Gattuso, L. & Lacasse, R. ***Les Mathophobes: une expérience de réinsertion au niveau collégial***. College de Vieux-Montréal, 1986: Centre de documentation collégiale #709292; Collette, J.-P. ***Mesure des attitudes des étudiants du collège I à l'égard des mathématiques: rapport de recherche***, DGEC, Que. 1978: Centre de documentation collégiale #715026.

Aside from these prudential considerations, knowledge and skills in science and mathematics are important for an educated person's capacity to understand crucial aspects of the world in which we live.

3.3 The Liberal Arts Program is now a province wide program, approved by the Ministry of Education in September 2002. The program is currently offered by 12 colleges (7 Anglophone, 5 Francophone), its French name being *Histoire et Civilisation*. The program was initiated at the Lafontaine Campus of Dawson College in 1983, designed as an integrated curriculum of required courses and student choices: that is, it practiced a thoroughgoing program approach well before the current reform emphasized that approach to college education. Six other Anglophone colleges then adopted this design. The Ministerial document which signaled the current reform mentioned Liberal Arts as a model. In the current form of the program, given since 1994, the teaching of mathematics and science[3] are part of a curriculum, which is integrated 'horizontally' - within each semester - and 'vertically' - across semesters. Also, from the start, Liberal Arts has had a thorough description in terms of transferable abilities (*compétences*).[4] At Dawson, the program received a very positive evaluation twice: in 1996-97 and 1998-99.[5]

3.3.1 The Dawson College Liberal Arts program consists of a sequence of 18 required courses including English, Humanities, History, Classics, Philosophy, Religion, Research Methods, Art History, Mathematics and Logic, and History of Science. In addition to fulfilling other

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[3] The problem of mathematics and science teaching and learning is discussed from other viewpoints than those informing Liberal Arts, which are not taken up in this study: e.g. gender, or ethnicity: see Davis, F. ***Feminist pedagogy in the physical sciences***. Vanier College, St. Laurent, Que. 1993: Centre de documentation collégiale #701989. Fennema, E. & Leder, G. C. ***Mathematics and gender***. Teachers College Press, Columbia University, N.Y. 1990; Powell, A. B. & Frankenstein, M. ***Ethnomathematics: challenging eurocentrism in mathematics education***. S.U.N.Y., Albany, N. Y. 1997; Rossner, S. V. ed. ***Teaching the majority***. Teachers College Press, Columbia University, N. Y. 1995; M. Nickson, "What is multicultural mathematics?", in Ernest, Paul. ***Mathematics teaching: the state of the art***. Falmer Press, N. Y. 1989, pp. 236-240.

[4] Liberal Arts Writing Committee. ***Liberal Arts program experimentation: program description***. Dawson College, November 1995. The official description of Liberal Arts by objectives and standards is in Aaron Krishtalka, Diane Charlebois (Writing Committee), ***Liberal Arts Program 700.B0***, Diplôme d'Études Collégiales (DEC), Dawson College, January 2003.

[5] Milkman K. & Krishtalka, A. ***Liberal Arts (700.02) (Histoire et Civilisation) Report on the second student questionnaire***. Dawson College, 1997. Dawson College. ***Liberal Arts evaluation report***, and appendices, 3 v. June 1999.

requirements, French and Physical Education, students choose 6 courses in other programs to complete their DEC. The required courses are arranged in 4 terms so that the opportunity for student choice increases after the first term. Student choices are constrained by rules that limit the number of new disciplines they may take and the number of courses they may take within a discipline.[6] The *Principles of Mathematics and Logic* course is given in the second term of the program; the *Science: History and Methods* course is given in the third term of the program.

3.4 The students admitted into this program are successful students, judging by their high schools records. All have relatively high Secondary V averages (please see section 5, Student Portrait, below); the criteria of admission to the program ensure this. We have related research results for previous cohorts in the formal evaluations of this program, done in 1998-1999[7] and during 1995-1997, and previously[8]. This previous work was aimed at the assessment of the program as a curricular whole. It was not focused on mathematics and science in particular; however, it did give us data about the overall success of the program in terms of students' achievement and attitudes.

For the sake of greater clarity, Mathematics and Science are considered separately in the following detailed discussion.

3.5 **Mathematics**: A central concept in the Liberal Arts program, employed in virtually all of its courses, is the idea of an argument; and a central ability emphasized in all courses is the construction, presentation and evaluation of arguments. The concept of an argument[9] is central to the practice (therefore, the teaching) of critical thinking, which is one of the four basic abilities imparted by the program.[10] The decision whether a statement is worthy of belief, or whether an action ought or ought not be done, essentially involves assessing the arguments that support the belief or action being considered. In this program, the concept of an argument is essential to the teaching approach

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[6] The content description of the Liberal Arts Program is available at the Dawson College Web site: www.dawsoncollege.qc.ca, under programs of study. See Appendix 6, Program Outline.

[7] Dawson College. ***Liberal Arts evaluation report***, and its appendices, 3 v. June 1999.

[8] Krishtalka, A. & Milkman, K. ***Liberal Arts program 700.02 integration and ability objectives***...Dawson College, 1996; Milkman K. & Krishtalka, A. ***Liberal Arts (700.02) (Histoire et Civilisation) Report on the second student questionnaire***. Dawson College, 1997.

[9] An argument may be defined, somewhat informally, as follows: a complex linguistic device through which reasons, usually called premises, are given in support of a statement under discussion, usually called the conclusion of the argument.

[10] ***Liberal Arts program experimentation: program description***. Dawson College, November 1995. See Appendix 6, Progam Abilities description.

in the course devoted to mathematics, 360-124-94, *Principles of Mathematics and Logic*. The emphasis that the other program courses give to argument supports the approach in this course.

3.6 Deductive reasoning (which involves the ideas of deductive argument, valid argument, invalid argument, sound argument and unsound argument) and inductive reasoning[11] (which involves the ideas of good and bad inductive argument) form the opening segment of the course. On this basis, the claim is made to students that mathematics is essentially an argument driven subject, as are the other subjects in the program. The intention is to show students the essential unity of all of our fields of knowledge, and to shrink the psychological distance that students generally assume exists between mathematics and other subjects[12], e.g. history, with which they feel more comfortable. Students' response often is surprise, because for various reasons, they have come to think of mathematics as a disconnected series of rote calculative schemes.

3.7 The further claim is made to students that for professional mathematicians the discipline of mathematics has an essential activity, namely, the construction of a special kind of argument, called a proof. The rest of the course builds on this claim. We show that proofs are a type of valid deductive argument, presented *via* a device called an axiom system. We explicate the nature of an axiom system; it sets the environment for producing mathematical arguments. We then start doing mathematics (i.e., proofs) in such fields as (the axiomatic development of) algebra, geometry, linear algebra, and calculus or statistics. However, constraints of time limit the number of fields that can be tackled in one semester. For the two cohorts involved in this project, the arrangement of material in the course is: logic, the nature of axiom systems, and axiomatic number theory; and the extension of the axiomatic approach to different types of numbers, linear algebra and group theory.

3.8 **Mathematics in the Liberal Arts curriculum**: In presenting mathematics in this way, we connect it to other subjects presented in the program.[13] For example, in the previous *Introduction to*

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[11] For a discussion of deductive and inductive approaches in mathematics, see Hiebert, J., ed. ***Conceptual and procedural knowledge, the case of mathematics***. Hillsdale, New Jersey, 1986, especially pp. 242-49.

[12] This phenomenon is discussed in, e.g., House, P. A. & Coxford, A. F., eds. ***Connecting mathematics across the curriculum***. National Council of Teachers of Mathematics, Reston, Va. 1995.

[13] L. & W. Reimer, "Connecting mathematics with its history: a powerful, practical linkage", in House & Coxford, eds. ***Connecting mathematics across the curriculum***, pp.104-14;

Ancient Philosophy, we discuss ancient Greek mathematics, e.g., the work of Pythagoras, employing the idea of a proof. As well, in the concurrent *Introduction to Modern Philosophy*, René Descartes' *Meditations* are considered as an attempt to deduce the nature of the world from as few premises as possible. The mathematics course also takes up the question of why science is so connected to mathematical accounts of the nature of reality, both deductive and inductive. This question is prominently studied in the subsequent *Science: history and methods*. The concurrent history course, *Western World, Renaissance to Revolution*, describes the historical context of the 16th and 17th century revolution in science and the development of mathematics.

3.9 Science: The attitudes of many of our students to science are similar to those they evince regarding mathematics. They respect science because of its evident successes, they suspect science because of its feared power or social consequences, and they generally regard science as complex, esoteric and largely beyond their own understanding. The close connection between science and mathematics reinforces these views[14]. The students' assumption here seems to be that science is somehow a separate compartment of activity, isolated by its language and its methods. However, as pointed out above, the program is designed to lead students to understand that the contrary is true, that the sciences and mathematics are integrally connected to the whole tradition of seeking, developing and validating of knowledge in the West.

3.10 Science in Liberal Arts: The development of modern science, its theories, discoveries and conceptual problems form the main theme of the course *Science: History and Methods*. The modern concept of a theory - of theoretically informed explanation and the uses of evidence - is a central idea of the Liberal Arts program, and is addressed directly in the Science course and in the other courses in the Ministerial Block of the program[15]. The Science course proceeds from the 16th to the 20th century; its texts, discussion, empirical observations and laboratory experiments exhibit the main developments of modern scientific knowledge and theory in astronomy, cosmology, physics, biology, etc. Concurrent and following courses take up similar periods with respect to their history, political,

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and D. J. Whitin, "Connecting literature and mathematics", in House & Coxford, pp. 134-41. These articles deal with primary and secondary school teaching.

[14] Schwab, J. J. ***Science, curriculum, and liberal education***. University of Chicago Press, Chicago, Ill. 1978.

[15] In the revision of the Liberal Arts program, taking effect in September 2003, the 'Ministerial Block' of required courses is found within the "Specific Education Component" of the new description by 'objectives and standards'.

intellectual and social development, art and architecture, literature, etc. In this way, the ideas of science are demonstrated together with the body of ideas and events that form their context, and students are thus encouraged to understand the sciences as a part of our intellectual and technical development[16] - a phenomenon they are accustomed to treat as familiar and tractable.

3.11 The Science course has two primary aims. One is to set forth clearly the main concepts upon which modern science is based and proceeds (e.g. gravitation, force, magnetic or electric field, biological evolution, etc.), and to demonstrate to students that they can understand these concepts even though they may not be doing detailed work in the related sciences. The explication of scientific method is the second aim and a major feature of the *Science* course, and is an important theme in other required courses. This method is a central mark of modernity and involves the following ideas: theory, testing a theory, the importance of empirical observation in testing a theory, the centrality of mathematics to theory construction and theory testing[17]. The account of scientific discoveries, and of what we now know as mistakes (e.g. the various ether theories, the phlogiston theory) involve the demonstration of the uses of scientific evidence and argument - both deductive and inductive - and connect the *Mathematics and Logic* with the *Science* course and the *Modern Philosophy* course.

4. Research Methodology, General objectives

4.1 The main objective of the project was, over a three-year period and for two student cohorts, to evaluate the success of the program approach in the Liberal Arts program at Dawson College in changing students' attitudes towards mathematics and the sciences.

4.2 A subsidiary objective was, over a three year period and for two student cohorts, to evaluate the success of the program approach in the Liberal Arts program at Dawson College in students' learning of the mathematics and science components of the program; it being understood that such the evaluative method would consist in correlating cohort attitudes with grade performance.

4.3 **Research Protocol and Procedures**: All the data gathered in this research project were obtained from two sources: questionnaires completed by student respondents and the available

[16] The contextualization of science teaching is discussed in Schwab, J. J. ***The teaching of science as enquiry***. Harvard University Press, Harvard, Mass. 1964.

[17] Giere, R. ***Understanding scientific reasoning***. 2nd ed. Holt, Rinehart, N. Y. 1984, pp. 45-95.

records of their high school and college grades. We used a research protocol that preserved the anonymity of subjects and respondents. Our protocol employed a coding technique that also permitted the tracking of individual subjects' data.

4.4 Research Protocol: Since we were the researchers as well as the teachers of the experimental cohorts in the mathematics and science courses, we took no part in administering questionnaires to students. All questionnaires were administered by a third party, a paid research assistant. The research assistant carried out the steps necessary to guarantee the anonymity of respondents, as follows:

4.4.1 the questionnaires were administered during class periods without any prior notice. The research assistant read out the instructions pertaining to the questionnaires (see Appendix 2), distributed them to the students present, and collected the completed questionnaires;

4.4.2 the instructions asked the students to write the last 4 digits of their student number at the top of the questionnaire sheet. The research assistant then treated each response sheet as follows: she multiplied the students' 4 digit numbers by a number that was known only to herself and was deposited in a sealed envelope with the director of research at Dawson College. On each sheet, she then tore off the student's 4 digit number and wrote instead the computed number. She then delivered to us the completed questionnaires, whose identifying number could not be linked to any particular student but could act as the research code for individual subjects.

4.4.3 Student grades were treated in the same manner. The spreadsheets containing their high school or college grades were given to the research assistant who coded them by the above procedure. This enabled us to track high school grades, questionnaire responses and college grades for each subject in a cohort while adhering to strict anonymity of respondents.

4.5 Procedures: Each cohort completed 5 questionnaires, Qu1…Qu5. Each questionnaire comprised no more than 10 questions. All the questionnaires were qualitative in character, and elicited responses on an attitudinal scale, e.g. extremely positive, positive, neutral, negative, extremely negative. (Please see Appendix 2 for the questionnaires.) The qualitative responses were analyzable and expressible quantitatively, so as to make possible the assembly of a statistical picture of attitudinal change.

4.5.1 For each of the cohorts under study we obtained from the Dawson registrariat the Sec. IV and Sec. V mathematics and science grades of first semester students.

4.5.2 Qu1…Qu5 were administered as follows:

Schedule of questionnaires: attitudinal data

Questionnaire	cohort 2000	cohort 2001
Qu1. On initial attitudes to mathematics and science	Sept. 2000	Sept. 2001
Qu2. During course: on attitudes to mathematics at mid-term	March 2001	March 2002
Qu3. End course: on attitudes to mathematics	May 2001	May 2002
Qu4. During course: on attitudes to science at mid-term	October 2001	October 2002
Qu5. End course: on attitudes to science	Dec. 2001	Dec. 2002

4.5.3 The data on student grades were collected as follows:

Data gathering schedule

Type of data	Cohort 2000	Cohort 2001
Sec. IV & V mathematics & science grades	Sept. 2000	Sept. 2001
Principles of Math & Logic 360-124-94 grades	May 2001	May 2002
Science: history & method 360-125-94 grades	Jan. 2002	Jan. 2003
Other Cegep math & science courses: grades	Jan. 2001 May 2001 Jan. 2002 May 2002	Jan. 2002 May 2002 Jan. 2003 May 2003

4.5.4 Our analysis of data compared students' initial attitudes towards mathematics and science with their attitudes towards these subjects during the relevant courses and at their completion of those courses. Our aim was to measure the degree of change, if any, and to analyze the statistical aspects of such change for this relatively small population. Data tracking techniques (see 4.4.2 and 4.4.3, above) also allowed (i) analysis of attitudinal change for individual subjects; and (ii) correlation between observed attitudinal change and academic performance.

Findings and Results

5. Portrait of the student cohort 2000

5.1 Cohort 2000

5.1.1 Population: The entering cohort 2000 population in the Fall semester, September – December 2000, was 75 (Table 1, column B). This number grew to 87 (Table 1, column A) in January 2001due to students who transferred into Liberal Arts from other programs, and students repeating the Mathematics course (from the 1999 cohort in the previous year).

5.1.2 The students' high general averages (Table 1, column I, or Table 2, column K) show that these are well qualified and successful high school students.

5.2. High School Mathematics background: Please refer to Table 1,below, for column references.

5.2.1 Column C shows that while 68 of 75 students (for whom High School data were available) took and passed the minimum mathematics requirement for graduation, only 4 of these were content with the minimum requirement. Column G shows that the great majority (54) also took and passed the advanced high school mathematics course, which is the requirement for admission to the Commerce program, and is one of the requirements for admission to Cegep Science programs.

5.2.2 Columns H and I show the difference between the performance of these students in their mathematics courses as compared to their over-all performance. Their general average, including mathematics, is almost a grade level higher than their mathematics grades.

5.2.3 The centile distribution of the students' grade performance shows that, for each of the high school courses, a significant majority had grades in the top three centiles:
in Math 436 (column C)…51 of 68 had grades in the top three centiles;
in Math 514 (column D)…12 of 15 had grades in the top three centiles;
in Math 536 (column E)… 32 of 54 had grades in the top three centiles.

5.2.4. Conclusion: The results shown above (5.2.2., 5.2.3.) support the conclusion that by most measures, these students were successful in their high school mathematics, but less so than in their other studies. This might indicate that they have experienced difficulty in mathematics, a hypothesis that is tested in this project by investigating their expressed attitudes toward mathematics upon entry to Dawson.

TABLE 1 - Student Portrait, cohort 2000, Mathematics background

centile range	A Total No. subjects	B No. of Students cohort 2000	C No. with Math 436 / 436 only	D No. with Math 514 / 514 only	E No. with Math 536	F No. with Math 436 and 514	G No. with Math 436 and 536	H Math Aggregate* Average	I Students' General Average
	87	75	68 / 4	15 / 6	54	10	54		
[% average]			*76.2*	*75.6*	*71.6*			74.3	82.66
90 - 100			9 [13.2%]	0	3 [5.5%]			3 [4.1%]	4 [5.5%]
80 - 89.9			20 [29.4%]	6 [40%]	14 [25.9%]			20 [27.4%]	53 [72.6%]
70 - 79.9			22 [32.4%]	6 [40%]	15 [27.8%]			26 [35.6%]	16 [21.9%]
60 - 69.9			16 [23.5%]	3 [20%]	13 [24.1%]			21 [28.8%]	0
0 - 59.9			1 [1.5%]	0	9 [16.7%]			3 [4.1%]	0
Did not take			*5*	*58*	*19*				
no math data		2							

NOTE: 'Total No. of Subjects' includes Column B + repeating students and transfer students.
Column B includes all first term students entering Liberal Arts, Fall 2000.
Math 436 (local variants: 564-436, 068-436, 064-436, etc.) is the minimum requirement for Sec.V.
Math 514 (local variants: 568-514, 068-514, etc.) is the advanced version of 436.
Math 536 (local variants 568-536, 564-536, 068-536, 064-536, etc.) is the most advanced high school math course, required for entry into Cegep Science programs.
Columns C, D, E, H and I show the number of students in each centile, and the corresponding percentage.
Column H: *Aggregate Average denotes the sum of all grade in mathematics courses divided by the total number of students who took the relevant math courses.

5.3. High School Science Background:

Please refer to Table 2, below, for column references.

5.3.1 Column C shows that while 64 of 75 students (for whom data were available) took and passed the minimum science requirement for graduation, 29 of these were content with the minimum requirement, and 35 took more than the minimum. Columns G, H, and I show that, of the 35, 16 took one other science course, 18 took 2 other science courses, and only 1 took 3 other science courses. Thus, 19 of the 64 students were qualified to apply for admission to Cegep Science programs.

5.3.2 Columns J and K show the difference between the performance of these students in their science courses as compared to their over-all performance. This difference is not as marked as in Mathematics, but it is nonetheless noteworthy. Their general average, including mathematics, is half a grade level higher than their science grades.

5.3.3 The centile distribution of the students' grade performance in science shows that, for each of the high school courses, a significant majority had grades in the top three centiles:

in Science 416 (column C)…49 of 64 had grades in the top three centiles;

in Physics 584 (column D)…15 of 25 had grades in the top three centiles;

in Chemistry 584 (column E)… 17 of 22 had grades in the top three centiles.

in Biology 534 (column F)… 11 of 12 had grades in the top three centiles.

5.3.4 Conclusion: The results shown above (5.3.2., 5.3.3.) support the conclusion that a majority (35/64) of this cohort decided well before their high school graduation year not to qualify for admission to Cegep science programs. The relatively small number, 19, who did qualify for admission to Cegep science did not apply despite their relatively good grade performance in the sciences. These results might indicate that they see the sciences as involving difficulty, excluding mathematics, a hypothesis that is tested in this project by investigating their expressed attitudes toward science upon entry to Dawson.

TABLE 2: Student Portrait, cohort 2000, Science background

centile range	A Total No. subjects	B No. of Students cohort 2000	C No. with Phy. Sci. 416 / only	D No. with Physics 584	E No. with Chemistry 584	F No. with Biology 534	G No. with C + 1 of D, E, or F	H No. with C + 2 of D, E, or F	I No. with 4 sci.	J Science Aggregate* Average	K Students' General Average
	87	75	64 / 29	25	22	12	16	18	1		
[% average]			*78.6*	*75.6*	*76.3*	*78.3*				77.5	82.66
90 - 100			13 [20.3%]	1 [4.0%]	2 [9.1%]	1 [8.3%]				6 [9.1%]	4 [5.5%]
80 - 89.9			23 [35.9%]	6 [24%]	9 [40.9%]	5 [41.7%]				23 [34.8%]	53 [72.6%]
70 - 79.9			13 [20.3%]	10 [40%]	6 [27.3%]	5 [41.7%]				21 [31.8%]	16 [21.9%]
60 - 69.9			12 [18.6%]	8 [32%]	3 [13.6%]	1 [8.3%]				14 [21.2%]	0
0 - 59.9			3 [4.7%]	0	2 [9.1%]	0				2 [3.0%]	0
did not take			*2*	*41*	*44*	*54*					
no sci. data		*9*									

NOTE: Column A, 'Total No. of Subjects', includes Column B + repeating students and transfer students.
Column B includes all first term students entering Liberal Arts, Fall 2000.
Physical Science 416 (local variants: 056-436, 556-430, etc.) is the minimum requirement for Sec.V.
Physics 584 (local variants: 554-584, 054-584) Chemistry 584 (local variants 551-584, 051-584)
Biology 534 (local variants 537-534,037-534, etc.)
Columns C, D, E, F, J and K show the number of students in each centile, and the corresponding percentage.
Column J: * Aggregate Average denotes the sum of all science grades divided by the total number of students .
who took the relevant courses

6. Portrait of the student cohort 2001

6.1 Population: The entering cohort 2001 population in the Fall semester, September – December 2001, was 73 (Table 3, column B). This number grew to 84 (Table 3, column A) in January 2002 due to students who transferred into Liberal Arts from other programs, and students repeating the Mathematics course (from the 2000 cohort in the previous year).

6.1.1 The students' high general averages (Table 3, column I, or Table 4, column K) show that these, like the 2000 cohort, are well qualified and successful high school students.

6.2. High School Mathematics background: Please refer to Table 3, below, for column references.

6.2.1 Column C shows that while 67 of 73 students (for whom High School data were available) took and passed the minimum mathematics requirement for graduation, only 2 of these were content with the minimum requirement. Column G shows that the great majority (49) also took and passed the advanced high school mathematics course, which is the requirement for admission to the Commerce program, and is one of the requirements for admission to Cegep Science programs. In these characteristics the 2001 cohort is very similar to the 2000 cohort.

6.2.2 Columns H and I show the difference between the performance of these students in their mathematics courses as compared to their over-all performance. The difference between their general average, including mathematics, and their mathematics average (6.39%) is significant but not as great as in the case of the 2000 cohort (8.36%).

6.2.3 The centile distribution of the students' grade performance shows that, for each of the high school courses, a significant majority had grades in the top three centiles:
in Math 436 (column C)…50 of 67 had grades in the top three centiles;
in Math 514 (column D)…12 of 18 had grades in the top three centiles;
in Math 536 (column E)… 34 of 49 had grades in the top three centiles;
in Other Math (column E1)… 6 of 8 had grades in the top three centiles.

6.2.4 Conclusion: The conclusion is the same as that reached for the 2000 cohort. The results (6.2.2., 6.2.3.) show that by most measures, the 2001 cohort students were successful in their high school mathematics, but more successful in their other studies. The same hypothesis stated in 5.2.4 is indicated here, and is tested by investigating their expressed attitudes toward mathematics upon entry to Dawson.

TABLE 3 - Student Portrait, cohort 2001, Mathematics background

centile range	A Total No. subjects	B No. of Students cohort 2001	C No. with Math 436 / 436 only	D No. with Math 514 / 514 only	E No. with Math 536	E1 No. with other math	F No. with Math 436 and 514	G No. with Math 436 and 536	H Math Aggregate* Average	I Students' General Average
	84	73	67 / 2	18 / 2	49	8	16	49		
[% average]			*77.6*	*73.6*	*76.8*	*84.3*			77.1	83.5
90 - 100			12 [17.9%]	0	7 [14.3%]	5 [62.5%]			7 [10.1%]	5 [7.3%]
80 - 89.9			19 [28.4%]	5 [27.8%]	12 [24.5%]	1 [12.5%]			23 [33.3%]	43 [62.3%]
70 - 79.9			19 [28.4%]	7 [38.9%]	15 [30.6%]	0			17 [24.6%]	21 [30.4%]
60 - 69.9			15 [22.4%]	6 [33.3%]	14 [28.6%]	2 [25.0%]			21 [30.4%]	0
0 - 59.9			2 [3.0%]	0	1 [2.0%]	0			1 [1.4%]	0
did not take			*2*							
no math data		*4*								

NOTE: 'Total No. of Subjects' includes Column B + repeating students and transfer students.

Column B includes all first term students entering Liberal Arts, Fall 2001.

Math 436 (local variants: 564-436, 068-436, 064-436, etc.) is the minimum requirement for Sec.V.

Math 514 (local variants: 568-514, 068-514, etc.) is the advanced version of 436.

Math 536 (local variants 568-536, 564-536, 068-536, 064-536, etc.) is the advanced high school math course, required for entry into Cegep Science programs.

Columns C, D, E, H and I show the number of students in each centile, and the corresponding percentage.

Column E1 shows the number of students with one math course in addition to 436, 514 or 536: seven took 436 and 536; one took 436 and 514.

Column H: *Aggregate Average denotes the sum of all grade in mathematics courses divided by the total number of students who took the relevant math courses.

6.3 High School Science Background: Please refer to Table 4,below, for column references.

6.3.1 Column C shows that while 68 of 73 students (for whom data were available) took and passed the minimum science requirement for graduation, 32 of these were content with the minimum requirement, and 36 took more than the minimum. Columns G, H, and I show that, of the 36, 16 took one other science course, 10 took 2 other science courses, and 10 took 3 other science courses. In addition, and unlike the 2000 cohort, 10 students took a total of 4 science courses. Thus, 20 of the 68 students were qualified to apply for admission to Cegep Science programs.

6.3.2 Columns J and K show the difference between the performance of these students in their science courses as compared to their over-all performance. In this cohort, there is virtually no difference (.09%) difference between their general average, including mathematics, and their average in science courses.

6.3.3 The centile distribution of the 2001 cohort grade performance in science shows that, for each of the high school courses, a significant majority had grades in the top three centiles:
in Science 416 (column C)…64 of 68 had grades in the top three centiles;
in Physics 584 (column D)…16 of 21 had grades in the top three centiles;
in Chemistry 584 (column E)… 20 of 23 had grades in the top three centiles.
in Biology 534 (column F)… 15 of 15 had grades in the top three centiles;
in Other Biology (column F1)… 7 of 8 had grades in the top three centiles.

6.3.4 Conclusion: The results in 6.3.2., 6.3.3. above, show that almost 50% (32/68) of this cohort decided well before their high school graduation year not to qualify for admission to Cegep science programs. It is noteworthy that these same students scored higher in their science course than in their general average. A relatively small number, 20, did qualify for admission to Cegep science. These students were successful in science, did trouble to get the mathematics prerequisites, and nonetheless elected not to apply to a cegep science program. The question, what attitudes toward science contribute to such results, is particularly interesting, and is among other questions taken up in this project.

TABLE 4: Student Portrait, cohort 2001, Science background

centile range	A Total No. subjects	B No. of Students cohort 2000	C No. with Phy. Sci. 416 / only	D No. with Physics 584	E No. with Chemistry 584	F No. with Biology 534	F1 No. with other Biology	G No. with C + 1 of D, E or F	H No. with C + 2 of D, E or F	I No. with 4 sci.	J Science Aggregate* Average	K Students' General Average
	84	73	68 / 32	21	23	15	8	16	10	10		
[% average]			*87.1*	*78.6*	*78.4*	*81.5*	*83.1*				83.4	83.5
90 – 100			30 [44.1%]	2 [9.5%]	6 [26.1%]	4 [26.7%]	2 [25.0%]				19 [27.5%]	5 [7.3%]
80 - 89.9			23 [33.8%]	11 [52.4%]	3 [13.0%]	3 [20.0%]	4 [50.0%]				25 [36.2%]	43 [62.3%]
70 - 79.9			11 [16.2%]	3 [14.3%]	11 [47.8%]	8 [53.3%]	1 [12.5%]				21 [30.4%]	21 [30.4%]
60 - 69.9			4 [5.9%]	3 [14.3%]	2 [8.7%]	0	1 [12.5%]				4 [5.8%]	0
0 - 59.9			0	2 [9.5%]	1 [4.3%]	0	0				0	0
did not take			*1*									
no sci. data		*4*										

NOTE: Column A, 'Total No. of Subjects', includes Column B + repeating students and transfer students.
Column B includes all first term students entering Liberal Arts, Fall 2001.
Physical Science 416 (local variants: 056-436, 556-430, etc.) is the minimum requirement for Sec.V.
Physics 584 (local variants: 554-584, 054-584) Chemistry 584 (local variants 551-584, 051-584)
Biology 534 (local variants 537-534,037-534, etc.) Other Biology are courses other than Biology 534 variants
Columns C, D, E, F, F1, J and K show the number of students in each centile, and the corresponding percentage.
Column J: * Aggregate Average denotes the sum of all science grades divided by the total number of students who took the relevant courses.

7. Cohort 2000, Results of the first attitudinal questionnaire, October 2000.

The results of this questionnaire, Table 5, show the students' attitudes toward Mathematics and Science during their first semester, but before they have taken the Mathematics and Logic course of the second semester or the Science: History and Methods course in the third semester.

7.1 Cohort 2000, attitudes toward Mathematics

Please refer to Table 5, below [Please see the text of the first questionnaire in Appendix 2]:

7.1.1 q1, q2 and q5: a far larger proportion of the students consider mathematics difficult, and their own attitude to it negative, than characterize mathematics as easy and their attitude to it positive. Yet, as the responses to q5 show, a majority rate their understanding of its aims and methods as good to excellent. The correlations in Table 6 reflect the above results: responses to q1 and q2 are positively correlated; the correlations of each with q5 show that a higher rating of understanding of the subject is associated with positive personal attitudes to mathematics and with the opinion that it is relatively easy.

7.1.2 q3 and q4: the striking result here is that a majority (33/61) consider teaching crucial, and that almost all (51/61) regard it as 'important' to 'crucial', as a factor in determining their attitude toward mathematics. Only about 15% (9/61) think subject matter is crucial in this regard; however, 72% (44/61) rate subject matter as 'important' to 'crucial'. Irrespective of students' performance in their high school mathematics courses, their rating of the importance of teaching and subject matter in deciding attitudes is relatively high.

7.1.3 Table 6, below, also shows positive correlations between the students' high school mathematics average grades and their responses to q1, q2 and q5. In the case of q5, higher high school math averages are associated with a higher rating of understanding of the subject. That there is virtually no correlation between high school math averages and students' rating of the importance of both teaching and subject matter as factors in determining their attitudes toward mathematics agrees with the result cited in 7.1.2.

7.1.4 Conclusion: The students have the opinion that they understand the nature of mathematics, while showing generally negative attitudes toward it. We conclude that they think they can identify correctly what it is about mathematics that they find difficult and off-putting.

7.2 Cohort 2000, attitudes toward Science: Table 5 [Please see the text of the first questionnaire in Appendix 2.]: the results found here are markedly different from those related to attitudes to mathematics (7.1 above).

Table 5: Cohort 2000, First Attitudinal Questionnaire, October 2000, Results:
Distribution by question of the number of responders in each response category.

Math Section

response	q1 Math as a subject	q2 personal attitude	q3 teaching as a factor	q4 subject matter as a factor	q5 present under-standing
10	1 [1.6%]	5 [8.2%]	33 [54.1%]	9 [14.8%]	3 [4.9%]
8	11 [18.0%]	11 [18.0%]	18 [29.5%]	35 [57.4%]	11 [18.0%]
6	18 [29.5%]	14 [23.0%]	8 [13.1%]	11 [18.0%]	21 [34.4%]
4	23 [37.7%]	21 [34.4%]	0	3 [4.9%]	21 [34.4%]
2	7 [11.5%]	7 [11.5%]	0	0	3 [4.9%]
N	1 [1.6%]	3 [4.9%]	2 [3.3%]	3 [4.9%]	2 [3.3%]
sum	61	61	61	61	61

Science Section

response	q6 Science as a subject	q7 personal attitude	q8 teaching as a factor	q9 subject matter as a factor	q10 present under-standing
10	5 [8.2%]	6 [9.8%]	22 [36.1%]	17 [27.9%]	3 [4.9%]
8	12 [19.7%]	17 [27.9%]	36 [59.0%]	28 [45.9%]	13 [21.3%]
6	25 [41.0%]	24 [39.3%]	1 [1.6%]	12 [19.7]	17 [27.9%]
4	18 [29.5%]	10 [16.4%]	1 [1.6%]	1 [1.6%]	24 [39.3%]
2	0	2 [3.3%]	0	0	2 [3.3%]
N	1 [1.6%]	2 [3.3%]	1 [1.6%]	3 [4.9%]	2 [3.3%]
sum	61	61	61	61	61

Cohort 2000, First Attitudinal Questionnaire, October 2000: Results
Averages of Responses grouped by students' high school math average and science average, by centiles

Avgs. of responses grouped by students' H.S. math average

No.	Avgs by centiles	q1	q2	q3	q4	q5
57*	Avgs - all responses	5.036	5.370	8.964	7.704	5.527
3	Math. Avg. 90-100%	6.667	7.333	8.667	7.333	8.000
15	Math. Avg. 80-89.9%	5.867	6.933	9.200	7.733	6.800
18	Math. Avg. 70-79.9%	4.824	4.533	8.824	7.600	4.941
18	Math. Avg. 60-69.9%	4.556	4.444	8.889	7.556	4.824
3	Math. Avg. below 60%	3.333	5.333	9.333	9.333	4.000

Avgs. of Responses grouped by H.S. Sci. average:

No.	Avgs by centiles	q6	q7	q8	q9	q10
51*	Avgs - all responses	6.118	6.392	8.627	8.041	5.680
4	Sci. Avg. 90-100%	6.500	5.500	9.500	8.000	7.000
18	Sci. Avg. 80-89.9%	6.667	6.444	8.222	8.222	6.556
15	Sci. Avg. 70-79.9%	6.267	7.200	8.933	8.143	5.333
12	Sci. Avg. 60-69.9%	5.167	5.500	8.667	7.636	4.545
2	Sci. Avg. below 60%	5.000	7.000	8.000	8.000	4.000

* number of respondents to questionnaire 1 for whom High School grade data were available for Math and/or Science.

7.2.1 q6: almost the same proportion (about 29%) of the students responding consider science to be easy to very easy as think it difficult. A larger proportion (41%) regard science as average on the same scale.

7.2.2 q7: more respondents rate their personal attitude toward science as positive to very positive than judge it negative to very negative. A larger proportion rate their attitude as neutral on the same scale. In Table 6 the responses to q6 and q7 are positively correlated; the correlation of q6 with q10 is almost identical to that of q1 and q5 in the mathematics section; but the q7-q10 correlation, relating personal attitude to rating of understanding, is less positive. It is noteworthy that the students' rating of their personal attitude toward science and their high school grades are independent.

7.2.3 q8 and q9: over 95% of the cohort consider teaching to be important to crucial in determining their attitudes toward science; while a lesser but large proportion take the same view of the subject matter of science.

7.2.4 q10: here the results should compared to those for q6. About 42.6% rate their own understanding of the aims and methods of science as only 'fair' to 'poor', while in q6 , significantly more respondents (nearly 70%) regard science as 'average' to 'very easy' as a subject. There is a positive correlation between the students' high school science grades and how they rate their understanding of the subject.

7.2.5 **Conclusion**: In general, these students do relatively well in science, yet their performance in the subject has no discernable relation to their personal attitude to it. This effect may be connected to the fact that all of the cohort take the minimal high school science requirement, which is their first exposure to the subject, while nearly half of the cohort take *only* that course.

Table 6: Cohort 2000 - Correlational analysis of first attitudinal questionnaire, Oct. 2000.

Correlations, Math section, between q1…q5

corr.q1-q2	corr.q1-q3	corr.q1-q4	corr.q1-q5
0.5876	-0.1168	-0.1486	0.6526
	corr. q2-q3	corr.q2-q4	corr.q2-q5
	0.0136	0.0696	0.6512
		corr.q3-q4	corr.q3-q5
		0.1872	-0.0642
			corr.q4-q5
			-0.1020

Correlations, Science section, between q6…q10

corr q6-q7	corr q6-q8	corr q6-q9	corr q6-q10
0.5342	0.1465	-0.2318	0.6580
	corr q7-q8	corr q7-q9	corr q7-q10
	0.1018	-0.0378	0.4527
		corr q8-q9	corrq8-q10
		0.0389	-0.0030
			corr q9-q10
			-0.0845

Correlations between q1…q5 and H.S. Math Avgs.

Corr. q1 & H.S. Math.	Corr. q2 & H.S. Math.	Corr. q3 & H.S. Math.	Corr. q4 & H.S. Math.	Corr. q5 & H.S. Math.
0.3846	0.4150	0.0827	-0.0686	0.5379

Correlations between q6…q10 and H.S. Science Avgs.

Corr. q6 & H.S. Sci.	Corr. q7 & H.S. Sci.	Corr. q8 & H.S. Sci.	Corr. q9 & H.S. Sci.	Corr. q10 & H.S. Sci.
0.2789	0.0563	0.0712	0.0556	0.4864

8. Cohort 2000, Mid and End Term Mathematics questionnaire results

Please see Tables 7 and 7A, below. These questionnaires were administered in the mid-term (March 2001) and at the end (May 2001) of the cohort's course, Principles of Mathematics and Logic. Since the number of responding students varied in each of the questionnaires (1, 2 and 3), the comparisons made below are with respect to percentages.

8.1 q1: The percentage of students who regard mathematics as difficult to very difficult drops from 49.2% to 42% to 39.4%. For the whole cohort (see Table 7, Chart), the averages of responses show a slight and continuous movement toward a less "difficult" view of the subject.

8.2 q2: The students' rating of their personal attitude to mathematics rises steadily across the 3 questionnaires. The rating of "neutral" to "very positive" rises from 49.2% to 58% to 66.6%, while the "negative" to "very negative" ratings falls from 45.9% to 40% to 31.1%. show a continuous movement toward the more positive part of the scale.

8.3 q3: The cohort's rating of the importance of teaching remains high, with the only significant change being a relative increase in the "important" category, and relative decreases in both the "crucial" and "neutral" categories across the three questionnaires. For the whole cohort (see Table 7, Chart), the averages of responses decline slightly.

8.4 q4: How the students rate subject matter, in both percentages and averages of responses, shows a rise toward the "crucial" category of the scale.

8.5 q5: How the students rate their understanding of mathematics varies across the three questionnaires. The second questionnaire shows a decrease (in the percentages and averages) in the "good" to "excellent" categories, and an increase in the "fair" to "poor" categories of responses. The responses to the third questionnaire reverse this result, showing an increase over the first questionnaire in the "good" to "excellent" categories, and a decrease in the "fair" to "poor" categories.

8.6 **Conclusion**: By their experience of the mathematics course, the students come to regard mathematics as somewhat less difficult, and their personal attitude becomes more positive. Their teacher dependence (their rating of the importance of teaching) declines slightly, while they judge the subject matter of mathematics more important. The most striking result concerns q5, illustrated in the chart in Table 7, and in 7A: the students' initial reaction to their course has them downgrading their understanding of mathematics; but at the end of the course, that assessment is reversed, and a higher than their initial rating of their understanding is the result. Of the 40 students who completed both Questionnaires 1 and 3, 19 rated their understanding of mathematics as unchanged, 13 as greater, 6 as less at the end of the term, and 2 gave no opinion. There is a high correlation (0.6670: see Table 7A) between the ratings of understanding in Questionnaire 3, at the end of the term, and the students' final grades in the Mathematics and Logic course.

TABLE 7

Cohort 2000, Mathematics, Responses to Second Questionnaire.

Cohort 2000, Mar 2001, year 1, term 2

response	q1	q2	q3	q4	q5
10	1 [2.0%]	4 [8.0%]	26 [52.0%]	11 [22.0%]	1 [2.0%]
8	12 [24.0%]	12 [24.0%]	17 [34.0%]	22 [44.0%]	10 [20.0%]
6	15 [30.0%]	13 [26.0%]	6 [12.0%]	15 [30.0%]	14 [28.0%]
4	15 [30.0%]	17 [34.0%]	0	0	15 [30.0%]
2	6 [12.0%]	3 [6.0%]	0	0	9 [18.0%]
N	1 [2.0%]	1 [2.0%]	1 [2.0%]	2 [4.0%]	1 [2.0%]
total	50	50	50	50	50
no data	37	37	37	37	37

Cohort 2000, Mathematics, Responses to Third Questionnaire.

Cohort 2000, May 2001, year 1, term 2

response	q1	q2	q3	q4	q5
10	1 [1.6%]	5 [8.2%]	28 [45.9%]	15 [24.6%]	4 [6.6%]
8	11 [18.0%]	15 [24.6%]	28 [45.9%]	35 [57.4%]	15 [24.6%]
6	24 [39.3%]	20 [32.8%]	3 [4.9%]	9 [14.8%]	21 [34.4%]
4	20 [32.8%]	16 [26.2%]	1 [1.6%]	0	12 [19.7%]
2	4 [6.6%]	3 [4.9%]	0	1 [1.6%]	8 [13.1%]
N	1 [1.6%]	2 [3.3%]	1 [1.6%]	1 [1.6%]	1 [1.6%]
total	61	61	61	61	61
no data	26	26	26	26	26

Cohort 2000: Chart of Averages of responses to Math Questionnaires 1 to 3.

Source data: avgs of responses on Math Questionnaires

	q1	q2	q3	q4	q5
QU1 *	5.20	5.52	8.85	7.72	5.66
QU2	5.47	5.88	8.82	7.83	5.14
QU3	5.50	6.10	8.77	8.10	5.83

* Note: the distributions of responses to Questionnaire 1 are found in Table 6.

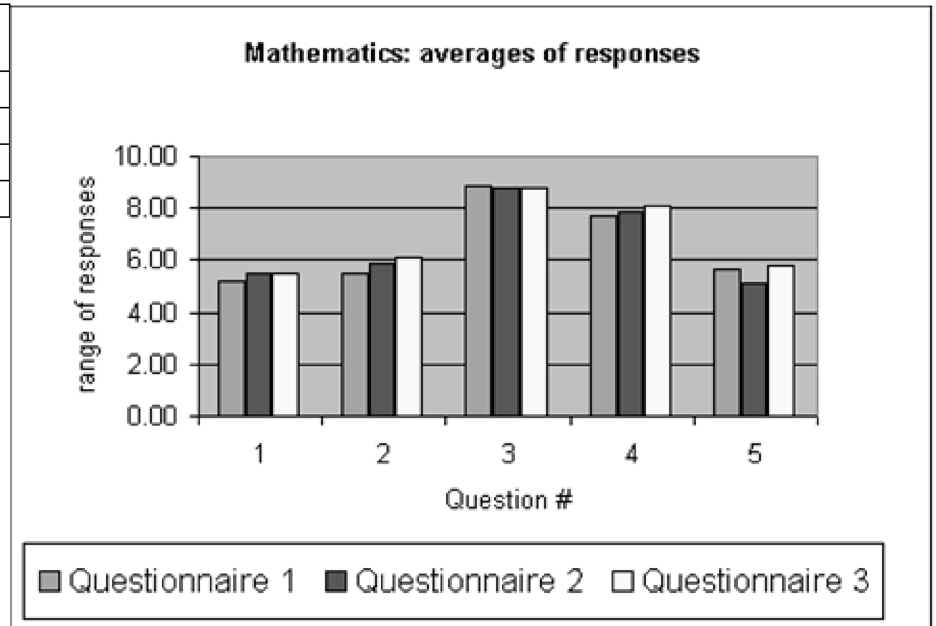

TABLE 7A: Cohort 2000, Mathematics, Responses to q5 on Questionnaires 1, 2, 3 for those students (42) who did at least 2 Questionnaires

Research Code	Math Qu. 1 Q5	Math Qu. 2 q5	Math Qu. 3 q5	360-124 Math/Logic Grades
98092	4	4	6	84.0
164537	6	8	4	76.0
164811	6	8	6	67.0
164948	4	6	8	82.0
165085	6	8	8	94.0
165222	2	2	2	20.0
165770	4	2	2	40.0
166044	6	6	6	86.0
166455	4	6	6	88.0
166592	8	2	dnd	92.0
166729	6	4	6	83.0
167414	4	4	4	66.0
171524	6	6	6	88.0
202075	8	6	8	94.0
202212	10	8	8	90.0
206870	4	2	dnd	20.0
256053	8	6	8	99.0
310168	4	6	6	84.0
310990	8	8	10	88.0
311127	4	2	4	87.0
311264	8	6	8	94.0
311401	4	6	6	96.0
311812	6	4	8	81.0
312360	4	6	2	82.0
312497	10	10	10	96.0
313319	6	4	8	78.0
313593	4	2	2	60.0
313867	4	4	6	75.0
314415	8	8	8	84.0
314552	6	2	6	84.0
448401	6	4	10	88.0
467033	6	6	6	81.0
467444	8	8	10	98.0
468677	8	4	8	80.0
486624	4	2	6	95.0
487446	6	6	6	86.0
530464	4	4	4	88.0
618281	N	N	N	68.0
648558	10	4	8	92.0
679931	2	2	2	60.0
1060654	N	4	8	84.0
1061202	4	4	4	78.0
	42	42	42	42

q5 responses compared in Qu.1, Qu.3			
same 19			
greater in Qu.3 13	**= 2** 11	**= 4** 2	
less in Qu.3 6	**= -2** 6	**= -4** 0	

q5 responses compared in Qu.1, Qu.2			
same 15			
greater in Qu.2 8	**= 2** 8	**= 4** 0	
less in Qu.2 17	**= -2** 13	**= -4** 2	**= -6** 2

q5 responses compared in Qu.2, Qu.3			
same 18			
greater in Qu.3 18	**=2** 10	**= 4** 7	**= 6** 1
less in Qu. 3 3	**= -2** 1	**= -4** 2	

Correlation between q5 of Qu.3 and final grades for all students (70) who completed the course: 0.6670

dnd = did not do the questionnaire
N = no opinion

9. Cohort 2000, Mid and End Term Science questionnaire results

Please see Tables 8 and 8A, below. These questionnaires were administered in the mid-term and at the end of the cohort's course, Science: History and Methods. Since the number of responding students varied in each of the questionnaires (1, 2 and 3), the comparisons made below are with respect to percentages.

9.1 q1: compared to their initial rating, the cohort comes to regard science as slightly more difficult during their science course. The significant drop occurs among students who initially rated science as either easy (from 19.7% to 16% to 9.1%) or very easy (from 8.2% to 0%).

9.2 q2: cohort ratings of personal attitudes to science show very slight changes across the 3 questionnaires: they become slightly more positive in mid term, and fall slightly below initial values at the end of the term. The significant changes occur in the "positive" to "very positive" response ranges: from 38.7% to 44% to 38.6%.

9.3 q3 and q4: cohort ratings of the importance of teaching and subject matter in determining attitudes stay in the "important" to "crucial" range across the questionnaires. In q3 (importance of teaching), the noteworthy change is the shift of the bulk of responses to the "crucial" category. In q4 (subject matter), it is that the proportion of responses in the "important" to "crucial" categories rises from an initial 73.8% to 94%, then falling slightly to 86.4%.

9.4 q5: as in q2, cohort ratings of understanding of science rise during the term slightly at mid term and fall slightly below initial ratings at end term.

9.5 **Conclusion**: compared to their high school experience, the students regard their college science as somewhat more difficult, and rate their personal attitudes toward it as somewhat more negative. Nevertheless, their rating of their grasp of the subject stays virtually unchanged. Of the 32 students (see Table 8A) who completed both Questionnaires 1 and 3, 9 rated their understanding of science as the same, 12 as greater, 10 as less at the end of the term, and 1 gave no opinion. This may be explained by the relative levels of difficulty, respectively, of their high school and college courses. For almost half of the cohort their high school science course, the minimum graduating requirement, is the only science course they take. Their exposure to the basic theoretical concepts and laboratory methods of science is more pronounced and thorough in their third term college course.

9.5.1 In sharp contrast to the Mathematics results, there is virtually no correlation (see Table 8A) between students' rating of their understanding and their final grades in their science course. The students' responses may derive from their view that in "Science: History and Methods" they are studying history of science, not science proper, about which their opinions are by and large unchanged by the course. (Please see Teachers' Comments, Section 13, below.)

TABLE 8

cohort 2000, Science, Responses to Second Questionnaire

Cohort 2000, October 2001, year term, term 3

response	q1	q2	q3	q4	q5
10	0	6 [12.0%]	27 [54%.0]	16 [32.0%]	0
8	8 [16.0%]	16 [32.0%]	19 [38.0%]	31 [62.0%]	12 [24.0%]
6	25 [50.0%]	17 [34.0%]	0	2 [4.0%]	28 [56.0%]
4	15 [30.0%]	6 [12.0%]	2 [4.0%]	0	8 [16.0%]
2	1 [2.0%]	3 [6.0%]	1 [2.0%]	0	1 [2.0%]
N	1 [2.0%]	2 [4.0%]	1 [2.0%]	1 [2.0%]	1 [2.0%]
total	50	50	50	50	50
no data	37	37	37	37	37

cohort 2000, Science, Third Questionnaire

Cohort 2000, December 2001, year term, term 3

response	q1	q2	q3	q4	q5
10	0	2 [4.5%]	24 [54.5%]	12 [27.3%]	1 [2.3%]
8	4 [9.1%]	15 [34.1%]	15 [34.1%]	26 [59.1%]	8 [18.2%]
6	25 [56.8%]	17 [38.6%]	2 [4.5%]	4 [9.1%]	17 [38.6%]
4	12 [27.3%]	7 [15.9%]	1 [2.3%]	0	16 [36.4%]
2	1 [2.3%]	2 [4.5%]	1 [2.3%]	0	1 [2.3%]
N	2 [4.5%]	1 [2.3%]	1 [2.3%]	2 [4.5%]	1 [2.3%]
total	44	44	44	44	44
no data	43	43	43	43	43

Cohort 2000: Chart of Averages of responses to Science Questionnaires 1 to 3.

Source data: avgs. Of responses on Science Questionnaires

	q1	q2	q3	q4	q5
QU 1 *	6.13	6.51	8.63	8.10	5.69
QU 2	5.63	6.67	8.79	8.57	6.08
QU 3	5.52	6.29	8.73	8.30	5.63

* Note: the distributions of responses to Questionnaire 1 are found in Table 6A.

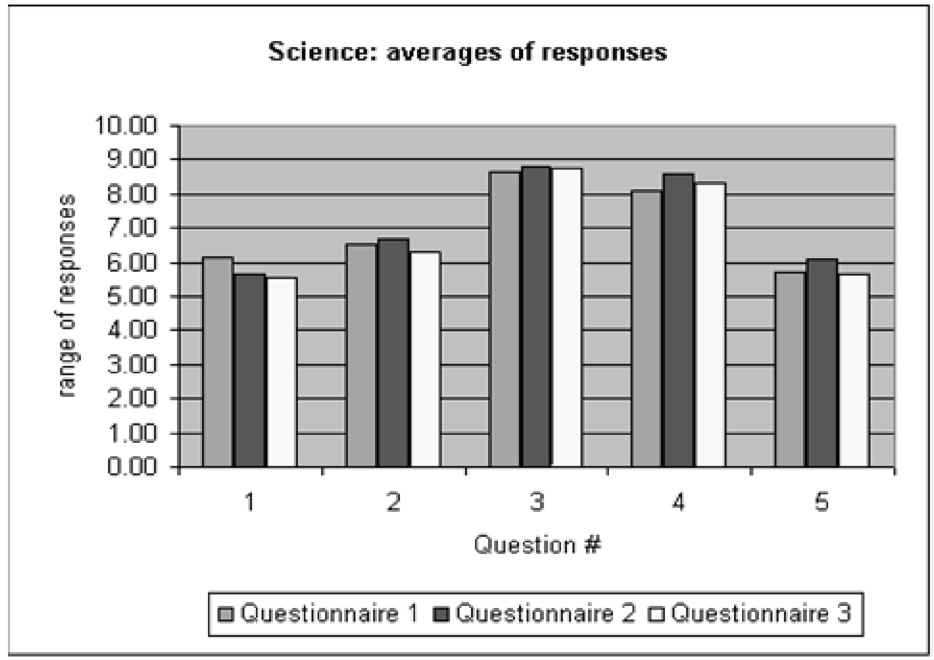

TABLE 8A: Cohort 2000, Science, Responses to q5 on Questionnaires 1, 2, 3 for those students (44) who did at least 2 Questionnaires.

Note: q10 of Qu.1 is the same as q5 in Qu.2 and Qu.3

Research Code	Science Qu. 1 q10	Science Qu. 2 q5	Science Qu. 3 q5	360-125-94 Hist. Of Sci. Grades
164537	6	4	dnd	83
164811	4	6	dnd	75
164948	4	4	10	80
165085	4	8	dnd	84
165770	8	6	6	75
166044	4	6	4	84
166455	4	6	6	91
166729	6	4	4	87
167414	6	6	4	77
171524	6	6	6	87
202075	8	8	6	90
202212	8	8	8	84
202349	4	4	4	76
256053	8	6	6	90
310168	4	8	8	86
310442	8	6	dnd	70
310990	8	8	dnd	85
311127	4	6	4	90
311401	4	6	6	85
311538	6	6	6	85
311812	4	6	6	81
312497	8	8	4	81
313319	4	4	6	75
313456	8	6	4	74
313593	4	6	4	71
313867	4	6	6	60
314415	6	6	dnd	78
347980	6	6	dnd	72
435660	4	6	6	73
447442	4	6	dnd	49
447990	6	4	6	67
448401	4	8	8	82
467033	10	8	8	88
468677	8	6	dnd	81
486624	6	6	8	81
486761	4	6	4	76
487446	8	8	dnd	82
530464	4	6	6	84
608006	2	6	8	77
618281	N	N	N	80
648558	10	2	4	81
679931	6	4	dnd	82
1060654	6	8	4	87
1061202	4	4	dnd	87
	44	44	44	44

q5 responses compared in Qu.1, Qu.3			
same			
9			
greater in Qu.3	**= 2**	**= 4**	**= 6**
12	8	2	2
less in Qu.3	**= -2**	**= -4**	**= -6**
10	7	2	1

q5 responses compared in Qu.1, Qu.2				
same				
15				
greater in Qu.2	**= 2**	**= 4**	**= 6**	
17	13	4	0	
less in Qu.2	**= -2**	**= -4**	**= -6**	**= -8**
11	10	0	0	1

q5 responses compared in Qu.2, Qu.3				
same				
16				
greater in Qu.3	**= 2**	**= 4**	**= 6**	
6	5	0	1	
less in Qu.3	**= -2**	**= -4**	**= -6**	
9	7	2	0	

Correlation between q5 of Qu.3 and final grades for all students (63) who completed the course: 0.1055

dnd = did not do the questionnaire

N = no opinion

10. Cohort 2001, Results of the first attitudinal questionnaire, October 2001.

The results of this questionnaire, Table 9 below, show the second cohort's attitudes toward Mathematics and Science during their first semester, but before they have taken the Mathematics and Logic course of the second semester or the Science: History and Methods course in the third semester.

10.1 Cohort 2001, attitudes toward Mathematics

Please see Table 9. The text of the first questionnaire is in Appendix 2.

10.1.1 q1, q2 and q5: a roughly equal proportion of the students consider mathematics difficult, and their own attitude to it negative, as characterize mathematics as easy and their attitude to it positive. Still, as the responses to q5 show, a higher proportion of the students rate their understanding of the aims and methods of mathematics as good to excellent rather than fair to poor. These results are different than those obtained for cohort 2000. The correlations in Table 10 reflect the degree of difference: responses to q1 and q2 are still positively correlated but less so than for cohort 2000. The same result is observable in the correlations of q1 and q2 with q5: the correlations are less positive, but still show that a higher rating of understanding of the subject is associated with positive personal attitudes to mathematics and with the opinion that it is relatively easy.

10.1.2 q3 and q4: the striking result here, as with cohort 2000, is that a majority (38/69) consider teaching crucial, and that almost all (60/69) regard it as 'important' to 'crucial', as a factor in determining their attitude toward mathematics. Only about 14.5% (10/69) think subject matter is crucial in this regard; however, 58% (40/69) rate subject matter as 'important' to 'crucial'. As with cohort 2000, irrespective of performance in their high school mathematics courses, students' rating of the importance of teaching and subject matter in deciding attitudes is relatively high.

10.1.3 Table 10 shows positive correlations between the students' high school mathematics average grades and their responses to q1, q2 and q5. The correlations for q2 and q5 are considerably weaker than were found for cohort 2000. In all other respects, the correlational results for the two cohorts are virtually identical (see 7.1.3).

10.1.4 Conclusion: The students in cohort 2001, like their colleagues in cohort 2000, believe that they understand the nature of mathematics, while they show generally negative attitudes toward it. The same conclusion applies: they think they can identify correctly what it is about mathematics that they find difficult and off-putting.

TABLE 9: Cohort 2001, First Attitudinal Questionnaire, October 2001, Results:
Distribution by question of the number of responders in each response category.

Mathematics section

response	q1 Math as a subject	q2 personal attitude	q3 teaching as a factor	q4 subject as a factor	q5 present under-standing
10	5 [7.2%]	8 [11.6%]	38 [55.1%]	10 [14.5%]	6 [8.7%]
8	17 [24.6%]	16 [23.2%]	22 [31.9%]	40 [58.0%]	15 [21.7%]
6	25 [36.2%]	19 [27.5%]	3 [4.3%]	14 [20.3%]	34 [49.3%]
4	18 [26.1%]	18 [26.1%]	3 [4.3%]	3 [4.3%]	8 [11.6%]
2	4 [5.8%]	7 [10.1%]	2 [2.9%]	1 [1.4%]	5 [7.2%]
N	0	1 [1.4%]	1 [1.4%]	1 [1.4%]	1 [1.4%]
sum	69	69	69	69	69

Science section

response	q6 Science as a subject	q7 personal attitude	q8 teaching as a factor	q9 subject as a factor	q10 present under-standing
10	2 [2.9%]	4 [5.8%]	34 [49.3%]	17 [24.6%]	4 [5.8%]
8	18 [26.1%]	28 [40.6%]	32 [46.4%]	39 [56.5%]	21 [30.4%]
6	38 [55.1%]	20 [29.0%]	0	10 [14.5%]	23 [33.3%]
4	7 [10.1%]	10 [14.5%]	1 [1.4%]	2 [2.9%]	17 [24.6%]
2	4 [5.8%]	6 [8.7%]	2 [2.9%]	1 [1.4%]	4 [5.8%]
N	0	1 [1.4%]	0	0	0
sum	69	69	69	69	69

Cohort 2001, First Attitudinal Questionnaire, October 2001: Results:
Averages of responses grouped by students' high school math average and science average, by centiles.

Avgs. of responses grouped by students' high school math average

No.	Avgs by centiles	q1	q2	q3	q4	q5
69 *	Avgs all responses	6.029	6.000	8.676	7.618	6.265
7	Math Avg 90-100%	9.143	7.714	8.571	8	8.286
23	Math Avg 80-89.9%	6.435	6.609	8.364	7.565	7
17	Math Avg 70-79.9%	5.333	5.733	9.067	7.429	6.133
21	Math Avg 60-69.9%	4.632	5	8.842	7.579	5.158
1	Math Avg below 60%	10	4	4	6	6

Avgs. of responses grouped by students' high school science average

No.	Avgs by centiles	q6	q7	q8	q9	q10
69 *	Avgs all responses	6.203	6.412	8.754	8.000	6.116
19	Sci. Avg 90-100%	6.333	6.111	8.778	8.444	6.111
25	Sci. Avg 80-89.9%	6.4	6.72	9.04	8	6
21	Sci. Avg 70-79.9%	6.105	6.444	8.421	7.474	6.316
4	Sci. Avg 60-69.9%	4	4.667	8.667	8.667	5.333
0	Sci. Avg below 60%	0	0	0	0	0

* Number of respondents to Questionnaire 1 for whom high school data were available for Math and/or Science.

10.2 Cohort 2001, attitudes toward Science

Please see Table 9, below. The results found here are markedly different from those related to attitudes to mathematics (10.1 above).

10.2.1 q6: About 29% of the students responding consider science to be 'easy' to 'very easy', while 16.9% think it difficult. This result is different than that obtained for cohort 2000 (see above, 7.2.1.) A larger proportion (55.1%) regards science as average on the same scale.

10.2.2 q7: As in cohort 2000, more respondents rate their personal attitude toward science as positive to very positive than judge it negative to very negative. Only 29% (20/69) rate their attitude as neutral on the same scale. In Table 10 the responses to q6 and q7 are positively correlated; the correlation of q6 with q10 is almost identical to that of q1 and q5 in the mathematics section; but the q7-q10 correlation, relating personal attitude to rating of understanding, is slightly less positive. As with cohort 2000, the students' rating of their personal attitude toward science and their high school grades are independent.

10.2.3 q8 and q9: The results here are almost identical to those for cohort 2000. Nearly 95% of the cohort consider teaching to be important to crucial in determining their attitudes toward science; while a lesser but large proportion take the same view of the subject matter of science.

10.2.4 q10: here the results are less striking than in the case of cohort 2000 (see Table 6). Comparing the responses to q10 and q6, 30.4% rate their understanding of the aims and methods of science as fair to poor, while in q6 significantly more respondents, about 84%, regard science as average to very easy as a subject. As shown on Table 10, there is virtually no correlation between the students' high school science grades and how they rate their understanding of the subject. This result differs markedly from the analogous correlation obtained for the 2000 cohort (see Table 6).

10.2.5 Conclusion: In general, these students do relatively well in science, yet their performance in the subject has no discernable relation to their personal attitude to it. This effect may be connected to the fact that all of the cohort take the minimal high school science requirement, which is their first exposure to the subject, while nearly half of the cohort take *only* that course.

TABLE 10

Cohort 2001 – Correlational Analysis of the first attitudinal questionnaire, Qu.1, Oct. 2001

Correlations, Math Section, between q1…q5

corr. q1-q2	corr. q1-q3	corr. q1-q4	corr. q1-q5
0.5142	-0.3185	0.0945	0.5833

corr. q2-q3	corr. q2-q4	corr. q2-q5
-0.0738	0.1108	0.4705

corr. q3-q4	corr. q3-q5
-0.0235	-0.2638

corr. q4-q5
0.1641

Correlations, Science Section, between q6…q10

corr. q6-q7	corr. q6-q8	corr. q6-q9	corr. q6-q10
0.3746	0.2829	0.1519	0.5788

corr. q7-q8	corr. q7-q9	corr. q7-q10
0.2660	-0.0522	0.4445

corr. q8-q9	corr. q8-q10
0.3327	0.0791

corr. q9-q10
0.2707

Correlations between q1…q5 and H.S. Math avgs.

Corr. q1 & H.S. Math	Corr. q2 & H.S. Math	Corr. q3 & H.S. Math	Corr. q4 & H.S. Math	Corr. q5 & H.S. Math
0.3738	0.2004	-0.0319	0.0188	0.4140

Correlations between q6…q10 and H.S. Science avgs.

Corr. q6 & H.S. Sci	Corr. q7 & H.S. Sci	Corr. q8 & H.S. Sci	Corr. q9 & H.S. Sci	Corr. q10 & H.S. Sci
0.2434	0.1217	0.1182	0.1821	0.0364

11. Cohort 2001, Mid and End Term Mathematics questionnaire results

Please see Table 11 and 11A, below. These questionnaires were administered in the mid-term (March 2002) and at the end (May 2002) of the cohort's course, Principles of Mathematics and Logic. Since the number of responding students varied in each of the questionnaires (1, 2 and 3), the comparisons made below are with respect to percentages.

11.1 q1: The percentage of students who regard mathematics as difficult to very difficult drops from 31.9% to 28.5% and then rises slightly to 29.7%. For the whole cohort (see Table 11, Chart), the averages of responses show a slight movement toward a more "difficult" view of the subject. In these results it is clear, however, that from the outset and through the two following questionnaires, cohort 2001 generally viewed mathematics as less difficult compared to cohort 2000.

11.2 q2: The students' rating of their personal attitude to mathematics, from "neutral" to "very positive", rises from a comparatively high 62.3% to 73.2% and 72.2% across the 3 questionnaires. The "negative" to "very negative" ratings fall from 36.2% to 26.8% and 27.8%. Here, too, the results are markedly different than are found for the 2000 cohort.

11.3 q3: The cohort's rating of the importance of teaching is initially high (87.0% in the "crucial" and "important" categories), and reaches 100% in the third questionnaire at the end of the course. For the whole cohort (see Table 11, Chart), the averages of responses increase somewhat.

11.4 q4: The students' rating of the importance of subject matter (in determining their attitudes toward mathematics) in both percentages and averages of responses, rises in the "crucial" category of the scale across the three questionnaires.

11.5 q5: How the students rate their understanding of mathematics varies across the three questionnaires. The second questionnaire shows a marked decrease (in the percentages and averages) in the "good" to "excellent" categories, and an increase in the "fair" to "poor" categories of responses. The responses to the third questionnaire show an increase over the second, but are still below the initial values.

11.6 **Conclusion**: The students of the 2001 cohort show a different response than the previous cohort to their experience of the mathematics course. More of them have positive initial attitudes toward mathematics, which show a rise through the course. Fewer of them come to regard the subject as more difficult as their personal attitudes become more positive. Their teacher dependence (their rating of the importance of teaching) increases markedly by the end of the course, while more of them judge the subject matter of mathematics to be important in shaping their attitudes. Of 44 students (see Table 11A) who completed both Qu. 1 and Qu. 3, 14 rated their understanding of mathematics as unchanged, 8 as greater, 21 as less at the end of the term, and 1 gave no opinion. However, the correlation between the ratings of understanding in Qu. 3, at the end of the term, and the students' final grades in the Mathematics and Logic course remains high (.6455, see Table 11A).

TABLE 11

Cohort 2001, Mathematics, Responses to Second Questionnaire

Cohort 2001, March 2002, Year 1, term 2

response	q1	q2	q3	q4	q5
10	2 [3.6%]	6 [10.7%]	24 [42.9%]	11 [19.6%]	4 [7.1%]
8	14 [25.0%]	18 [32.1%]	27 [48.2%]	37 [66.1%]	10 [17.9%]
6	24 [42.9%]	17 [30.4%]	4 [7.1%]	7 [12.5%]	24 [42.9%]
4	12 [21.4%]	13 [23.2%]	0	0	14 [25.0%]
2	4 [7.1%]	2 [3.6%]	1 [1.8%]	0	3 [5.4%]
N	0	0	0	1 [1.8%]	1 [1.8%]
total	56	56	56	56	56
no data	24	24	24	24	24

Cohort 2001, Mathematics, Responses to Third Questionnaire

Cohort 2001, May 2002, Year 1, term 2

response	q1	q2	q3	q4	q5
10	5 [9.3%]	4 [7.4%]	29 [53.7%]	13 [24.1%]	6 [11.1%]
8	11 [20.4%]	15 [27.8%]	25 [46.3%]	29 [53.7%]	11 [20.4%]
6	22 [40.7%]	20 [37.0%]	0	9 [16.7%]	13 [24.1%]
4	9 [16.7%]	8 [14.8%]	0	3 [5.6%]	16 [29.6%]
2	7 [13.0%]	7 [13.0%]	0	0	8 [14.8%]
N	0	0	0	0	0
total	54	54	54	54	54
no data	26	26	26	26	26

Cohort 2001: Chart of averages of Mathematics questionnaires responses

Source data: avgs of responses on Math questionnaires

	q1	q2	q3	q4	q5
Qu1 *	6.03	5.91	8.55	7.51	6.17
Qu2	5.93	6.46	8.61	8.15	5.93
Qu3	5.93	6.04	9.07	7.93	5.67

* Note: the distribution of responses to Questionnaire 1
is found in Table 9.

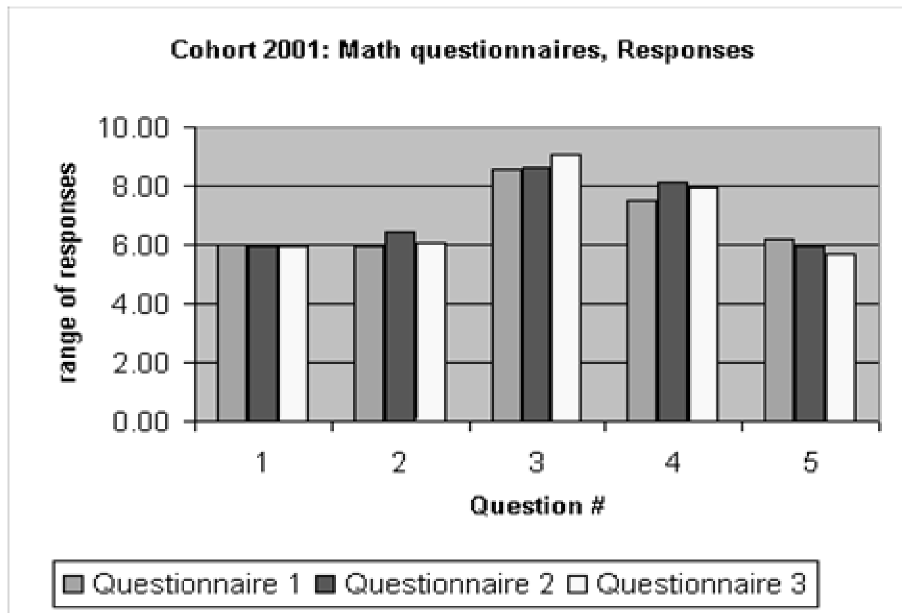

TABLE 11A: Cohort 2001, Mathematics, Responses to q5 on Questionnaires 1, 2, 3, for those students (44) who did at least two Questionnaires

Research Code	Math Qu. 1 q5	Math Qu. 2 q5	Math Qu. 3 q5	360-124 Math/Logic Grades
7809	6	4	4	70
8083	6	4	6	65
8905	6	6	6	80
9042	6	4	6	88
9179	8	6	6	93
9316	N	4	6	80
9864	10	8	6	88
80967	8	2	4	95
109874	6	6	4	91
110011	4	6	4	77
110696	2	2	4	92
135630	6	4	6	65
181662	6	4	4	88
181936	8	4	6	83
182073	10	6	8	85
182210	6	6	8	92
184128	6	8	4	25
184265	6	8	4	94
257012	6	6	6	88
257697	2	2	4	62
258108	4	2	4	82
258519	6	4	4	90
258930	6	8	6	74
259204	8	10	10	84
259341	6	4	4	70
259615	8	2	6	82
286741	6	6	6	70
341815	6	4	6	88
342363	4	4	2	62
398807	6	2	6	94
399081	8	6	8	90
399218	10	4	4	96
399355	6	6	6	88
399492	8	6	4	88
498954	10	6	6	93
534574	6	8	8	96
534848	6	6	6	30
534985	6	2	8	35
535122	6	10	10	92
535259	6	6	8	93
535670	6	6	4	60
674040	6	2	4	60
689932	8	4	4	dnd
695001	10	8	8	88
	44	44	44	44

q5 responses compared in Qu.1, Qu.3			
same 14			
greater in Qu.3 8	**= 2** 7	**= 4** 1	
less in Qu.3 21	**= -2** 15	**= -4** 5	**= -6** 1

q5 responses compared in Qu.1, Qu.2			
same 12			
greater in Qu.2 7	**= 2** 6	**= 4** 1	
less in Qu.2 24	**= -2** 14	**= -4** 7	**= -6** 3

q5 responses compared in Qu.2, Qu.3			
same 17			
greater in Qu.3 18	**= 2** 15	**= 4** 2	**= 6** 1
less in Qu.3 9	**= -2** 7	**= -4** 2	

Correlation between q5 of Qu.3 and final grades For those students (66) who completed the course: 0.6455

dnd = did not do the questionnaire

N = no opinion

12. Cohort 2001, Mid and End Term Science questionnaire results

Please see Table 12 and 12A, below. These questionnaires were administered in the mid-term and at the end of the cohort's course, Science: History and Methods. Since the number of responding students varied in each of the questionnaires (1, 2 and 3), the comparisons made below are with respect to percentages.

12.1 q1: compared to their initial rating, fewer of the cohort come to regard science as either easy or very easy during their science course. The significant drop occurs among students who initially rated science as easy (from 26.1% to 6.1%% to 11.3%). In the "very easy" category, there is almost no change (from 2.9% to 2.0% to 1.9%).

12.2 q2: cohort ratings of personal attitudes to science show changes across the 3 questionnaires: they become less positive in mid term, and rise slightly above initial values at the end of the term. These changes in the "positive" to "very positive" response ranges are from 46.4% to 34.7% to 49.0%, and are thus markedly different from the responses given by cohort 2000.

12.3 q3: cohort ratings of the importance of teaching in determining attitudes stay almost entirely in the "important" to "crucial" range across the questionnaires, reaching 100% at the end of the course. These responses are similar to those obtained for mathematics for the same cohort.

12.4 q4: students' ratings of the importance of subject matter rise from an initial 81.1% to 91.8%, then fall slightly to 90.6%.

12.5 q5: cohort ratings of understanding of science fall (from an initial 69.5% in the "good" to "excellent" categories) at mid term (51.0%), and rise to 62.3% at the end of the course.

12.6 **Conclusion**: cohort 2001 is similar to the previous cohort in regarding their college science as somewhat more difficult than their high school experience of science. However, the 2001 cohort shows a slight improvement in their personal attitude towards the subject, while the previous cohort rated their personal attitudes toward it as somewhat more negative. The 2001 cohort display a drop at mid-term and a small increase at end term in their rating of their understanding of the aims and methods of science. Of the 44 students (see Table 12A) who completed both Questionnaires 1 and 3, 20 rated their understanding of science as the same, 9 as greater, 15 as less at the end of the term. The explanation for these results is likely identical to that proposed for the 2000 cohort (see 9.5, above).

12.6.1 The correlation between the 2001 cohort's rating of their understanding and their final grades in their science course is very weak and negative (-0.1010: see Table 12A). This result is similar to the very weak analogous correlation found for science in the 2000 cohort. By contrast, the two analogous correlations for the 2000 and 2001 cohorts in mathematics are strong and positive (see 11.6, above).

TABLE 12

Cohort 2001, Science, Responses to Second Questionnaire

Cohort 2001, October 2002, Year 2, term 3

response	q1	q2	q3	q4	q5
10	1 [2.0%]	2 [4.1%]	25 [51.0%]	15 [30.6%]	3 [6.1%]
8	3 [6.1%]	15 [30.6%]	20 [40.8%]	30 [61.2%]	6 [12.2%]
6	23 [46.9%]	16 [32.7%]	3 [6.1%]	3 [6.1%]	16 [32.7%]
4	18 [36.7%]	14 [28.6%]	1 [2.0%]	0	14 [28.6%]
2	4 [8.2%]	2 [4.1%]	0	1 [2.0%]	9 [18.4%]
N	0	0	0	0	1 [2.0%]
total	49	49	49	49	49
no data	27	27	27	27	27

Cohort 2001, Science, Responses to Third Questionnaire

Cohort 2001, December 2002, Year 2, term 3

response	q1	q2	q3	q4	q5
10	1 [1.9%]	4 [7.5%]	32 [60.4%]	11 [20.8%]	3 [5.7%]
8	6 [11.3%]	22 [41.5%]	21 [39.6%]	37 [69.8%]	7 [13.2%]
6	26 [49.1%]	17 [32.1%][	0	3 [5.7%]	23 [43.4%]
4	15 [28.3%]	7 [13.2%]	0	1 [1.9%]	18 [34.0%]
2	5 [9.4%]	3 [5.7%]	0	1 [1.9%]	2 [3.8%]
N	0	0	0	0	0
total	53	53	53	53	53
no data	23	23	23	23	23

Cohort 2001: Chart of averages to Science Questionnaires 1 to 3, responses

Source data: avgs of responses on science questionnaires					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**
QU1 *	6.20	6.32	8.75	8.00	6.12
QU2	5.14	6.04	8.82	8.37	5.17
QU3	5.36	6.64	9.21	8.11	5.66

* Note: the distribution of responses to Questionnaire 1 is found in Table 9

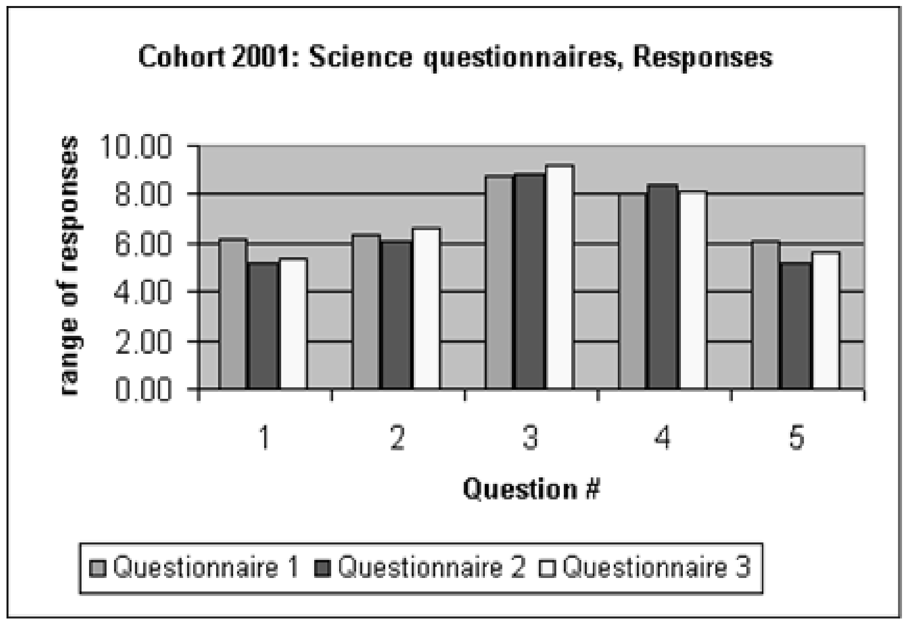

Table 12A: Cohort 2001, Science, Responses to q5 on Questionnaires 1, 2, 3.
for those students who (44) who took at least 2 Questionnaires
Note: q10 of Qu.1 is the same as q5 in Qu.2 and Qu.3

Research Code	Science Qu. 1 q10	Science Qu. 2 q5	Science Qu. 3 q5	360-125 Hist. of Sci. Grades
7809	6	4	4	81
8083	6	4	6	80
8905	6	6	6	85
9042	6	4	6	91
9179	6	6	6	90
9316	6	4	6	90
9864	8	8	6	82
80967	4	2	4	87
109874	4	6	4	87
110011	4	6	4	90
110696	4	2	4	81
135630	8	4	6	78
181662	6	4	4	87
181936	10	4	6	82
182073	10	6	8	85
182210	2	6	8	86
184128	2	8	4	42
184265	8	8	4	72
257012	6	6	6	84
257697	2	2	4	66
258108	4	2	4	86
258519	4	4	4	87
258930	8	8	6	75
259204	8	10	10	20
259341	8	4	4	82
259615	4	2	6	80
286741	6	6	6	85
341815	6	4	6	80
342363	4	4	2	72
398807	4	2	6	93
399081	8	6	8	88
399218	8	4	4	93
399355	6	6	6	91
399492	8	6	4	91
498954	6	6	6	86
534574	4	8	8	92
534848	6	6	6	60
534985	6	2	8	19
535122	6	10	10	87
535259	8	6	8	86
535670	6	6	4	71
674040	4	2	4	71
689932	8	4	4	87
695001	10	8	8	88
	44	44	44	44

q5 responses compared in Qu.1, Qu.3			
same 20			
greater in Qu.3 9	**= 2** 6	**= 4** 2	**= 6** 1
less in Qu.3 15	**= -2** 9	**= -4** 6	

q5 responses compared in Qu.1, Qu.2			
same 14			
greater in Qu.2 7	**= 2** 3	**= 4** 3	**= 6** 1
less in Qu.2 23	**= -2** 16	**= -4** 6	**= -6** 1

q5 responses compared in Qu.2, Qu.3			
same 17			
greater in Qu.3 18	**= 2** 15	**= 4** 2	**= 6** 1
less in Qu.3 9	**= -2** 7	**= -4** 2	

Correlation between q5 of Qu.3 and final grades
For those students (56) who completed the course: 0.1010

13. Teachers' Comments

One of the aspects of our research is that we served both as teachers *and* researchers in this project. Our research protocol (see above, section 4.3) made it possible for us to do this by preserving the anonymity of the students who answered the questionnaires. There was no chance that their responses on the questionnaires could influence their grades or affect our opinion of them.

13.1 Principles of Mathematics and Logic (360-124-94; 3 hours class, 2 hours lab per week) In informal conversation throughout the course, students said that [what might be termed] the 'calculative' aspect of mathematics was most significant in producing their negative attitude toward the subject. Since their view of the subject, especially at the onset, was that mathematics was essentially about quantity as expressed *via* number, their dislike of having to manipulate numbers was, they thought, what made them dislike mathematics.

13.2 One of the main goals of the course is to argue that, from the point of view of the professional mathematician, calculating, *per se*, is not at the heart of mathematics. Instead, a view is presented that the central task of mathematics is to produce proofs, where proofs are defined as a type of valid deductive argument. (See above, sections 3.5 - 3.7 for a discussion of the course.) In all three cohorts taught in this way during the research period, the students were able to negotiate the material of the course successfully, as measured by their grades (see above, Tables 7A, 11A and 16A) and their understanding expressed during class.

13.3 However, two facts must also be mentioned in this regard:

13.3.1 With some individual exceptions, students' negative attitudes towards the subject were not improved by their experience in the course, despite their relatively good results.

13.3.2 Despite their claims that it was calculation and manipulation of numbers and formulae that was the basis of their negative attitudes, they were quite comfortable during the parts of the course in which calculation was necessary, even in subjects with which they were not familiar, such as matrix algebra.

13.3.3 If the students are mistaken about what it is in mathematics that is off-putting to them, i.e. calculation, then what is it about the subject that truly is the basis of their negative attitude? Teaching experience in the course suggests that the students' basic difficulty is with **argument** and **abstraction** rather than calculation.

13.4 Argument: The idea of an argument is difficult for many students because it involves relationships between multiple statements that are not narrative but rather logical in nature. It is this type of relationship between statements in an argument that makes it complicated in ways for which many students are neither technically nor psychologically prepared.

13.5 Abstraction: Throughout the course many students had difficulty in recognizing what might be called the underlying general or abstract structure of an argument or of a mathematical expression. Without a grasp of such structures and their relationship to particular cases, both mathematics and logic become opaque and seem trivial and a type of drudgery. It is precisely the demonstration of general claims that provide mathematics and logic with their lucidity, cogency, power and beauty.

Example:

Most of the students remembered, although perhaps without much enthusiasm, the part of high school mathematics devoted to factoring quadratic equations. They learned what might be termed rules of thumb so that they could arrive at the following results:

a) $x^2 - 9 = (x-3)(x+3)$
b) $x^2 - 8x + 15 = (x-5)(x-3)$
c) $x^2 + 2x - 48 = (x+8)(x-6)$

Many students informally expressed their boredom with having had to do an interminable number of such examples. However, they seemed to be even more resistant to the introduction of the quadratic formula, which provides solutions for **all** quadratic equations, as follows:

If $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Many of the students did not recognize that the quadratic formula is to quadratic equations what the general structure of an argument is to its instances. These students found it difficult to see that solving the general case solves the infinite number of particular cases which share the form.

13.6 Science: History and Methods (360-125-94; 3 hours class, 2 hours lab/week)
The science course (see sections 3.9 – 3.11) is given by two faculty members, working as partners. The weekly 3 hours of classes, taken by an historian, deal with the historical development of modern science from the early 16th to the 20th century. The 2 hour laboratory period each week, supervised and conducted by a physicist, has students do (or in a few labs, watch) experimental exercises that demonstrate the meaning and application of key concepts, theories and procedures or methods of particular sciences, mainly astronomy, optics, cell biology and physics. Both teachers attend and give the classes and laboratory exercises, conduct discussions and answer questions.

13.7 All the students have had a basic high school science course; yet almost all of the discoveries, concepts and theories introduced in this History of Science course appear new to them, and for many students disturbing as well. Class discussions show that the main source of disturbance is the students= own realization that their accustomed, common sense views of many everyday phenomena (e.g. sunrise, projectile motion, heart function) are either in large part uninvestigated, or superficial, or mistaken, or simply false. Their general success in research papers, laboratory reports, and tests in the course shows that they do correct their misunderstandings, and do grasp many essential concepts and theories of modern sciences; the historical approach taken in the course does help to clarify and explain these ideas to them. But many students= unease or aversion to science remains, or even increases, and some are convinced that they understand science less at the end of the course than at the beginning. Thus understanding the detail of a theory in science or of its development is for many students not the same as understanding science.

13.8 One influencing factor revealed by class and informal discussions is that a few students who have had to abandon their accustomed opinions or estimation of what science is and does, find the new picture of science - however truthful it may be - more inimical or intimidating than what they had believed about science before. That science >has no room for feelings=, that science is firmly focused upon the phenomena it studies, and makes every effort to dissociate those phenomena from human beliefs and attributes - in short, that science avoids anthropomorphism - counts as a repelling feature of science for some students.

13.9 However, most students who keep their dislike of science, nonetheless admire in science the quest for a form of objectivity, and reject the view that science is insufficiently >touchy-feely=. Their complaints raise a basic difficulty. In order to give an account of physical phenomena beyond obvious ordinary language descriptions, some abstraction is required: either in ideas, i.e., theoretical abstractions strictly defined, or in symbolic terms that are manipulated by logical or mathematical procedures, and usually both. Furthermore, the abstractions can have a hierarchy of levels. It is the use of such abstractions - to apply them in explanation of particular, especially unfamiliar cases, or to combine them with components of another theory - that poses the greatest difficulty for many of these students. The core of the difficulty seems to be <u>not</u> what the students identify - the <u>complexity</u> of scientific theories: students are well able to explain theories of science cogently and in some detail. Rather, the problem seems to be the students= hesitancy or confusion faced with the logical exercise of matching the general theoretical claims (which they do grasp) to instances of those claims (which may be unfamiliar to them). Thus, for example, the student who can give an excellent account of Einstein=s theory of light as composed of photons, and of Snell=s law of refraction, finds it difficult to explain (using the idea of photons and Snell=s law) how a lens appropriately held in sunlight can produce combustion in a piece of paper. It may be noted, too, that for many students this difficulty is discipline-specific; the student who finds the above example difficult, may be able to explain easily an analogous problem in biology involving evolutionary theory and continental drift.

13.10 In both the Mathematics and the Science courses, there are students (their number differs somewhat from cohort to cohort) who have none of the difficulties identified in the above comments. These students take easily to the use of abstraction and argument in the courses and express appreciation for the importance of these concepts and for the fact that they are basic to the courses. (See General Conclusions, Section 14, below.)

13.11 Conclusions from teachers' comments:

13.11.1 In both courses independently of each other, the researchers identified the same difficulties experienced by students, namely, the application and use of abstraction and logical argument.

13.11.2 Both the experience of teaching and the results of the research support the conclusion that students' attitudes to mathematics and science are formed well before they reach their first year of Cegep studies. [Please see Recommendations, Section 15]

14. General Conclusions

14.1 By all measures, the students involved in this study are successful students. Most of them take and pass the mathematics courses required for admission to Cegep science. However, just over half of them take the science courses required for admission to science. Also, the students' high school mathematics averages are lower than their general averages. While their science averages are close to their general averages, the only science course half of them take is the minimum requirement for graduation. This is insufficient for admission to Cegep science. In addition, the students who do qualify for Cegep science evidently do not apply that program.

14.2 This result shows two things: that most of the students decide not to pursue science beyond high school (or even in high school) in their earlier high school years or before; and that (given their simultaneous pursuit of qualifications in mathematics) they take a different view of mathematics than of science, at least in high school. Further, a very few students attempt any more mathematics while in Cegep. The anecdotal evidence of students, teachers and college academic advisers is that the students consider mathematics as being a subject that might be useful in many career paths; while they consider science as a career path or vocation in itself, and have definitely excluded it as a choice for themselves. The students' asymmetry of attitudes consists in seeing mathematics as instrumental in several groups of fields, while they see science itself as such a group.

14.3 The above conclusion, suggesting an important difference between students' attitudes toward mathematics and science, is supported by the analysis of questionnaire results. The students' rating of their understanding of the aims and methods of mathematics is highly correlated with their respective grades in the Mathematics/Logic course **in all three cohorts** (see Appendix 3 for the 2002 Cohort results and the chart of correlations below). By contrast, the students' analogous rating in science (in the two experimental cohorts) is largely independent of how well they do in their Cegep Science course. This result for science shows the same pattern as the students' attitudes in high school for both cohorts: in high school, as well, the correlations between students' attitudes and grades are higher for mathematics than for science. It may be noted that these correlations for science are in most cases weak.

Chart of correlations of responses to q5 of QU3 with Final Grades, All Cohorts

	cohort 2000	cohort 2001	cohort 2002
Correl. q5/QU3: **Math** grades	0.6670	0.6455	0.5723
Correl. q5/QU3: **Sci.** grades	0.1055	-0.1010	

q5: rating of present understanding of aims and methods of Mathematics, Science in QU.3
at the end of the course

14.3.1 The result given in 14.3, above, coheres with the observations stated in teachers' comments (section 13, above) regarding the students' different conceptions of mathematics and science. The result illustrates the strength of students' decision not to pursue science in their studies.

14.4 In both mathematics and science it is generally true that the student cohorts, measured by the averages of their responses, show no significant improvement of attitudes toward either subject as a result of their required college courses, even though they do well in both. One cohort shows a statistically significant decline in their assessment of their understanding of the aims and methods of science.

14.5 The main difference between the experimental cohorts relates to mathematics: it resides in their respective assessments of their understanding of the aims and methods of mathematics at the end of the mathematics/logic course. In cohort 2000, responses showed a sense of improved understanding, whereas in cohort 2001 the analogous responses showed a decline. In cohort 2002 this decline was even more marked and forms part of a pattern of decline from initial values in the responses to most questions. It should be added, however, that students in all of the cohorts did well in the mathematics and logic course.

14.6 Notwithstanding declines (or rises) in average responses across the questionnaires, in every cohort there are individuals whose attitudes toward mathematics and science either show marked improvement over their initial opinions during and after the mathematics/logic course and the science course, or show no change from relatively positive initial opinions.
The following table shows the number of students in each cohort who reported improved attitudes (question 2) to mathematics and science at the end of their respective courses. In all cohorts, except for cohort 2001, mathematics, students with improved attitudes to mathematics or science did not. On the average, have higher grades than those whose attitudes remained the same or showed a decline. In the case of the exception, those with an improved attitude had, on the average, final grades in mathematics 10% higher than other students in the class (86% v. 76%).

Note: **n** represents the number of students in each cohort who responded to both Questionnaires 1 and 3.

cohort	**Mathematics**		**Science**	
	n =	**q2 improved**	**n =**	**q2 improved**
2000	47	15 [31.9%]	36	8 [22.2%]
2001	49	8 [16.3%]	48	17 [35.4%]
2002	56	11 [19.7%]		

14.7 It may be added that in all experimental cohorts the students' generally good performance (as measured by their grades) suggests that they did grasp and were able to articulate the conception of mathematics and science presented in their respective courses.

15. Recommendations

15.1 The results of this project clearly indicate that students in all of the experimental cohorts have arrived at their views of mathematics and science and attitudes towards those subjects well before their graduation from high school. This suggests that a detailed analysis of high school students' views and attitudes would be instrumental in determining when, and for what reasons, their ideas are formed. The authors of this study will be undertaking such an analysis through their participation in the 2003 FQRSC (Fonds Québecois de la Recherche sur la Société et la Culture) research project, “A Study of the factors influencing success and perseverance in careers in science of CEGEP students”, primary researcher, Steven Rosenfield, Vanier College.

15.2 The teachers’ comments (see Section 13, above) point to one particular type of difficulty that students encounter in the Liberal Arts mathematics and science courses: the difficulty involves the use of abstraction in argument, especially when the abstractions are in symbolic form, and when the students are asked to proceed from general forms of arguments to particular instances, and *vice versa*. It would seem reasonable to suggest, therefore, that the students should be exposed to the study of symbolic argument (formal logic) integrated with their training in mathematics and science early in their high school years. This suggestion envisages that part of the students’ training in high school mathematics would be devoted to explicating the nature of the subject as a system of argumentation designed to demonstrate general truths; and that students’ high school science training would include some emphasis on the logical structure of scientific theories and their relation to empirical test.

Appendix 1: instructions to students

Samples of instructions to students for completion of Math and Science questionnaires

Instructions for the administration of the Liberal Arts questionnaire to first term students. Sept. 2001

Please read the following instructions to the class:

This questionnaire is part of a three year research project at Dawson College that investigates the teaching and learning of mathematics and science in the Liberal Arts program.

The researchers are Ken Milkman and Aaron Krishtalka. I am …, acting as research assistant in this project.

This questionnaire tries to find out the attitudes of first semester Liberal Arts students towards mathematics and science as subjects that they have experienced in High School Sec. IV and Sec. V.

Anonymity of responses is an important feature of this research project. All the information collected in this research project and in this questionnaire is treated anonymously. That is, the anonymity of responding students is guaranteed by the method of analyzing the students= responses. This method ensures that students= names or other identifying clues (such as handwriting) cannot be associated with student responses.

The method is as follows:

Students write the last four digits of their respective student numbers on the blank first page of the questionnaire.

I will encode this number to transform it into a different larger number in a way unknown to the two researchers. This allows anonymous data tracking.

I will place the new encoded number on the second page of the questionnaire, discard and shred the blank first page, and give the second page to the researchers.

Are there any questions?

Please write the last four digits of your student number on the blank first page of the questionnaire.

Then answer the questions on the second page by circling the appropriate response. When you are finished, please hand the completed questionnaire - both pages - to me.

Appendix 1, continued

Instructions for the Science questionnaire for second term Liberal Arts students. (December 2001)

Please read the following instructions to the class:

I am ...

This is the second questionnaire that you have been asked to respond to in this course. This questionnaire, like the previous ones, is part of a three year research project here at Dawson that investigates the teaching and learning of science and mathematics in the Liberal Arts program.

The researchers are Ken Milkman and Aaron Krishtalka. I am acting as research assistant in this project.

This second questionnaire, too, looks at the attitudes of Liberal Arts students towards science as a subject, at the end of the third semester. The questions ask for responses based on your experience of science in the Liberal Arts course, Science: History and Methods, 360-125-94.

Anonymity of responses is an important feature of this research project. All the information collected in this research project and in this questionnaire is treated anonymously. That is, the anonymity of responding students is guaranteed by the method of analyzing the students= responses. This method ensures that students= names or other identifying clues (such as handwriting) cannot be associated with student responses.

The method is as follows:
Students write the last four digits of their respective student numbers on the top of the questionnaire. I will encode this number to transform it into a different larger number in a way unknown to the two researchers. This allows anonymous data tracking.
I will place the new encoded number on the questionnaire, shred the top portion, and give the rest of the questionnaire page to the researchers.

Are there any questions?

Please write the last four digits of your student number in the space provided at the top of the questionnaire.
Then answer the questions by circling the appropriate response.
When you are finished, please hand the completed questionnaire to me. Thank you for participating in this project.

Appendix 2: Sample questionnaires

Mathematics/Science Attitude Questionnaire October 2000

In each of the following questions, please circle one of the responses provided in the scale below the question.

Please base your responses on your experience of mathematics and science (general science, physics, chemistry, biology) in Sec. IV and Sec. V.

1. **How do you regard mathematics as a subject?**

   very easy easy average difficult very difficultno opinion

2. **What is your personal attitude toward the subject of mathematics?**

   very positive positive neutral negative very negative no opinion

3. **How do you rate teaching as a factor in determining your attitude toward mathematics?**

   crucial important neutral not important negligible no opinion

4. **How do you rate the nature and content of mathematics as a factor in determining your attitude toward this subject?**

   crucial important neutral not important negligible no opinion

5. **How do you rate your present understanding of the nature of mathematics as a subject?**

   excellent very good good fair poor no opinion

6. **How do you regard science as a subject?**

   very easy easy average difficult very difficult no opinion

7. **What is your personal attitude toward the subject of science?**

   very positive positive neutral negative very negative no opinion

8. **How do you rate teaching as a factor in determining your attitude toward the sciences?**

   crucial important neutral not important negligible no opinion

9. **How do you rate the nature and content of the sciences as a factor in determining your attitude toward these subjects?**

   crucial important neutral not important negligible no opinion

10. **How do you rate your present understanding of the nature of science as a subject?**

    excellent very good good fair poor no opinion

Appendix 2, continued

Write the last four digits of your student number:

Mathematics Attitude Questionnaire Mid Term **March 2001**

In each of the following questions, please circle one of the responses provided in the scale below the question.

Please base your responses on your experience of mathematics in the ***Liberal Arts course, Principles of Mathematics and Logic, 360-124-94***.

1. **How do you regard mathematics as a subject?**

   very easy easy average difficult very difficult no opinion

2. **What is your personal attitude toward the subject of mathematics?**

   very positive positive neutral negative very negative no opinion

3. **How do you rate TEACHING as a factor in determining your attitude toward mathematics?**

   crucial important neutral not important negligible no opinion

4. **How do you rate SUBJECT MATTER as a factor in determining your attitude toward mathematics?**

   crucial important neutral not important negligible no opinion

5. **How do you rate your present understanding of the aims and methods of mathematics?**

   excellent very good good fair poor no opinion

6. **How many other college mathematics courses are you taking or have you taken at Dawson or elsewhere?** 0 1 2 3

Appendix 2, continued

Write the last four digits of your student number:

December 2001

Attitudes to Science Questionnaire, End of Term

In each of the following questions, please circle one of the responses provided in the scale below the question.

Please base your responses on your experience of science in the ***Liberal Arts course, Science: History and Methods, 360-125-94***.

1. **How do you regard science as a subject?**

   very easy   easy   average   difficult   very difficult   no opinion

2. **What is your personal attitude toward the subject of science?**

   very positive   positive   neutral   negative   very negative   no opinion

3. **How do you rate TEACHING as a factor in determining your attitude toward science?**

   crucial   important   neutral   not important   negligible   no opinion

4. **How do you rate SUBJECT MATTER as a factor in determining your attitude toward science?**

   crucial   important   neutral   not important   negligible   no opinion

5. **How do you rate your present understanding of the aims and methods of science?**

   excellent   very good   good   fair   poor   no opinion

6. **How many other college science courses are you taking or have you taken at Dawson or elsewhere?**   0   1   2   3

APPENDIX 3: Cohort 2002, Mathematics Responses

The inclusion of this cohort is an addition to the scope of the original research proposal, and was made possible by the fact that the Mathematics/Logic course is given in the Winter semester.

1. Portrait Data

1.1 A higher percentage (7) failed math 436 in this cohort (2002) than failed (1.5) in Cohort 2000 and cohort 2001. A **lower** percentage (7.04), by almost half or more got A in this cohort than did in cohort 2000 and 2001. (Conclusions based on Column Cs in portrait tables.)

1.2 A lower percentage in cohort 2002 scored 90 or better in math 536 than did in either cohort 2000 or 2001.

1.3 The portrait data show that this cohort is very similar to the other 2 cohorts in their high school math performance, except at the highest and lowest level of achievement. In this cohort, a lesser percentage of students scored above 90% and higher percentage students failed. Their general averages and their aggregate math averages are comparable.

2. First Attitudinal Questionnaire

2.1 q1: no significant differences, as compared with both 2000 and 2001.

q2: this cohort reports a higher percentage of responses in the upper ranges for personal as compared to both 2000 and 2001.

q3: no significant differences, as compared with both 2000 and 2001.

q4: the rating of the importance of subject matter for this cohort is shifted somewhat toward the center of the scale (i.e. they think subject matter is less important) as compared with both 2000 and 2001.

q5: This cohort rates their present understanding of math higher than both the 2000 cohort, and the 2001 cohort, as measured by the sum of the two top response categories. This suggests that they are more confident than previous cohorts of their understanding of the aims and methods of mathematics. The distribution of the students average responses, organized in centiles of their high school math averages, shows a similar pattern, especially in the comparison with the 2000 cohort (see Table 14).

2.2 The correlational analysis of responses of cohort 2002 to the mathematics section of the first attitudinal questionnaire (see Table 15) shows the same pattern as that of the 2000 and the 2001 cohorts (see Tables 6 and 10). Significant positive correlations are found between q1 [‘opinion of mathematics as a subject’] and q2 [‘attitude to the subject’]; between q1 and q5 [‘present understanding of the aims and methods of mathematics’]; and between q2 and q5.

2.3 The correlations between high school math averages and responses to q1…q5 are similar in all three cohorts except for q2 and q5. For q2, the correlation for cohort 2002 is weaker than for cohort 2000 but is almost identical to that of cohort 2001. For q5, the cohort 2002 correlation is weaker than those of cohorts 2000 and 2001. This would suggest that the confidence shown by cohort 2002 in their understanding of mathematics is less strongly linked to their performance in High School mathematics than in the other cohorts.

2.4 Cohort 2002 is similar to the previous cohorts. Their confidence in their understanding of math is high, but it does not seem to be linked with their success in the subject as measured by their high school grades. However, at Cegep their performance in the mathematics/logic course shows a high correlation with their rating (at the end of the course) of their understanding of the aims and methods of mathematics.

3. Second and third attitudinal questionnaire, cohort 2002.

3.1 The responses of cohort 2002 to q1, q2, q3 and q5 (see Table 16) show a decline from initial values. This decline is different than the pattern in cohort 2000 (see Table 7), in which responses showed a general rise from initial values by the end of the math/logic course; and different again from the cohort 2001 pattern (see Table 11), which showed some declines (q5) and some rises (q3). For q4 (rating of importance of subject matter in determining attitudes) there was a rise from initial values in all three cohorts.

3.2 In cohort 2000 and 2001 (see Tables 7A and 12A) the correlation between q5 [‘rating of present understanding of the aims and methods of mathematics’] in the final questionnaire and students final grades in the math/logic course is strongly positive. The analogous correlation for cohort 2002 (see Table 16A) is also strongly positive.

TABLE 13 - Student Portrait, cohort 2002, Mathematics background

Note: the second year of the 2002 cohort falls outside the scope of this project; since the Science course occurs in the second year, only Mathematics data is collected here.

centile range	A Total No. subjects	B No. of Students cohort 2001	C No. with Math 436 / 436 only	D No. with Math 514 / 514 only	E No. with Math 536	E1 No. with other math	F No. with Math 436 and 514	G No. with Math 436 and 536	H Math Aggregate* Average	I Students' General Average
	79	68	71 / 3	14 / 0	55	5	14	54		
[% average]			*75*	*81.8*	*73.4*	*78.8*			75.17	83.51
90 - 100			5 [7.04%]	4 [28.57%]	1 [1.81%]	1 [20.0%]			3 [4.17%]	5 [6.85%]
80 - 89.9			22 [30.99%]	4 [28.57%]	15 [27.27%]	0			18 [25%]	48 [65.75%]
70 - 79.9			23 [32.39%]	6 [42.85%]	21 [38.18%]	4 [80.0%]			29 [40.27%]	20 [27.40%]
60 - 69.9			16 [22.53%]	0	14 [25.54%]	0			20 [27.78%]	0
0 - 59.9			5 [7.04%]	0	4 [7.27%]	0			2 [2.78%]	0
did not take			*1*							
no math data		*6*								

NOTE: 'Total No. of Subjects' includes Column B + repeating students and transfer students.

Column B includes all first term students entering Liberal Arts, Fall 2002.

Math 436 (including local variants) is the minimum requirement for Sec.V.

Math 514 (including local variants) is the advanced version of 436.

Math 536 (including local variants) is the advanced high school math course, required for entry into Cegep Science programs.

Columns C, D, E, E1, H and I show the number of students in each centile, and the corresponding percentage.

Column E1 shows the number of students with one math course in addition to 436, 514 or 536: all five took 436 and 536.

Column H: *Aggregate Average denotes the sum of all grades in mathematics courses divided by the total number of students who took the relevant math courses.

TABLE 14: Cohort 2002, First Attitudinal Questionnaire, October 2002, Results:
Distribution by question of the number of responders in each response category.

Mathematics section

response	q1 Math as a subject	q2 personal attitude	q3 teaching as a factor	q4 subject as a factor	q5 present under-standing
10	3 [4.41%]	7 [10.29%]	35 [51.47%]	8 [11.77%]	3 [4.41%]
8	12 [17.65%]	19 [27.94%]	27 [39.71%]	37 [54.41%]	19 [27.94%]
6	24 [35.29%]	17 [25.0%]	4 [5.88%]	20 [29.41%]	28 [41.18%]
4	25 [36.77%]	23 [33.82%]	0	2 [2.94%]	15 [22.06%]
2	4 [5.88%]	2 [2.94%]	2 [2.94%]	1 [1.47%]	3 [4.41%]
N	0	0	0	0	0
sum	68	68	68	68	68

Science section

response	q6 Science as a subject	q7 personal attitude	q8 teaching as a factor	q9 subject as a factor	q10 present under-standing
10	3 [4.41%]	8 [11.77%]	34 [50.0%]	11 [16.18%]	3 [4.41%]
8	10 [14.71%]	21 [30.88%]	29 [42.65%]	42 [61.76%]	21 [30.88%]
6	36 [52.94%]	23 [33.82%]	3 [4.41%]	14 [20.59%]	21 [30.88%]
4	15 [22.06%]	8 [11.77%]	1 [1.47%]	1 [1.47%]	19 [27.94%]
2	3 [4.41%]	7 [10.29%]	1 [1.47%]	0	4 [5.88%]
N	1 [1.47%]	1 [1.47%]	0	0	0
sum	68	68	68	68	68

Cohort 2002, First Attitudinal Questionnaire, October 2002: Results:
Averages of responses grouped by students' high school math average and science average, by centiles.

Avgs. of responses grouped by students' high school math average

No.	Avgs by centiles	q1	q2	q3	q4	q5
65 *	Avgs all responses	5.51	6.15	8.8	7.45	6.18
3	Math Avg 90-100%	7.333	8	6.667	6.667	8
15	Math Avg 80-89.9%	6	6.933	8.4	7.467	6.533
28	Math Avg 70-79.9%	5.5	5.857	9.071	7.714	6.214
18	Math Avg 60-69.9%	4.889	5.556	9.111	7.111	5.556
1	Math Avg below 60%		8	8	8	6

Avgs. of responses grouped by students' high school science average

No.	Avgs by centiles	q1	q2	q3	q4	q5
65 *	Avgs all responses	5.88	6.44	8.77	7.88	6.12
13	Sci. Avg 90-100%	6.462	7.077	8.462	8.308	6.308
27	Sci. Avg 80-89.9%	6	6.385	8.444	7.852	6.667
21	Sci. Avg 70-79.9%	5.7	6.381	9.238	7.524	5.81
4	Sci. Avg 60-69.9%	4	6	8	6	4
0	Sci. Avg below 60%					

* Number of respondents to Questionnaire 1 for whom high school data were available for Math and/or Science.

Table 15: Cohort 2002 - Correlational analysis of first attitudinal questionnaire, Oct. 2002.

Correlations, Math section, between q1…q5

corr.q1-q2	corr.q1-q3	corr.q1-q4	corr.q1-q5
0.5254	-0.1010	-0.0645	**0.5508**

corr. q2-q3	corr.q2-q4	corr.q2-q5
0.1609	-0.1681	**0.5777**

corr.q3-q4	corr.q3-q5
0.1604	0.0291

corr.q4-q5
-0.2064

Correlations, Science section, between q6…q10

corr q6-q7	corr q6-q8	corr q6-q9	corr q6-q10
0.4520	-0.2990	-0.0904	**0.5217**

corr q7-q8	corr q7-q9	corr q7-q10
-0.0446	0.1842	**0.4519**

corr q8-q9	corrq8-q10
0.1450	-0.0383

corr q9-q10
0.0680

Note that q6…q10 in the science section are analogous to q1… q5 in the math section.

Correlations between q1…q5 and H.S. Math Avgs.

Corr. q1 & H.S. Math.	Corr. q2 & H.S. Math.	Corr. q3 & H.S. Math.	Corr. q4 & H.S. Math.	Corr. q5 & H.S. Math.
0.3397	0.1978	-0.2063	-0.0074	0.2790

Correlations between q6…q10 and H.S. Science Avgs.

Corr. q6 & H.S. Sci.	Corr. q7 & H.S. Sci.	Corr. q8 & H.S. Sci.	Corr. q9 & H.S. Sci.	Corr. q10 & H.S. Sci.
0.2859	0.1515	-0.2599	0.1500	0.2797

Note: only the mathematics section of this table is discussed in the body of the report. Completion of the science data falls outside the period approved for research.

Table 16

Cohort 2002, Mathematics, Responses to Second Questionnaire, Qu.2

Cohort 2002, March 2003, Year 1, Term 2

response	q1	q2	q3	q4	q5
10	0	4 [8.89%]	19 [42.22%]	9 [20.0%]	2 [4.44%]
8	7 [15.56%]	9 [20.0%]	20 [44.44%]	29 [64.44%]	7 [15.56%]
6	21 [46.67%]	10 [22.22%]	3 [6.67%]	7 [15.56%]	18 [40.0%]
4	12 [26.67%]	20 [44.44%]	2 [4.44%]	0	9 [20.0%]
2	5 [11.11%]	2 [4.44%]	0	0	9 [20.0%]
N	0	0	1 [2.22%]	0	0
total	45	45	45	45	45
no data	34	34	34	34	34

Cohort 2002, Mathematics, Responses to Third Questionnaire, Qu.3

Cohort 2002, May 2003, Year 1, Term 2

response	q1	q2	q3	q4	q5
10	0	2 [3.33%]	24 [40.0%]	11 [18.33%]	2 [3.33%]
8	8 [13.33%]	15 [25.0%]	27 [45.0%]	33 [55.0%]	6 [10.0%]
6	21 [35.0%]	20 [33.33%]	3 [5.0%]	12 [20.0%]	18 [30.0%]
4	22 [36.67%]	18 [30.0%]	5 [8.33%]	4 [6.67%]	27 [45.0%]
2	9 [15.0%]	5 [8.33%]	0	0	7 [11.67%]
N	0	0	1 [1.67%]	0	0
total	60	60	60	60	60
no data	19	19	19	19	19

Source data: avgs. Of responses on Math questionnaires

	q1	q2	q3	q4	q5
Qu 1 *	5.51	6.15	8.8	7.45	6.18
Qu 2	5.33	5.69	8.55	8.09	5.29
Qu 3	4.93	5.7	8.37	7.7	4.97

*Note: the distribution of responses to Questionnaire 1 is found in Table 14.

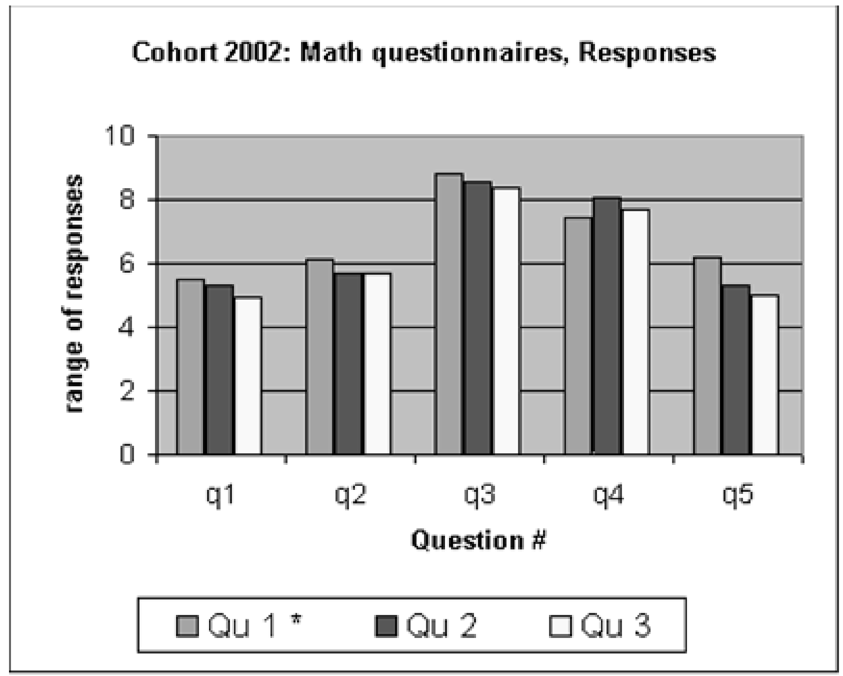

TABLE 16A: Cohort 2002, Mathematics, Responses to q5 on Qu.1, Qu.2, Qu.3

Research Code	Math Qu. 1 q5	Math Qu. 2 q5	Math Qu. 3 q5	360-124 Math/Logic Grades
34798	4	6	4	80
106586	4	4	4	81
106723	6	dnd	4	87
106860	8	2	6	76
106997	6	6	6	96
107134	2	2	4	81
107271	4	2	2	60
107682	4	6	4	80
108093	6	6	4	65
108641	6	6	4	66
108778	6	6	4	90
108915	6	2	2	67
109052	6	dnd	6	98
109326	8	10	10	94
147001	2	8	6	90
164537	4	4	4	85
164674	8	6	6	74
206870	dnd	2	4	75
406205	6	4	6	83
406479	2	2	2	63
407027	8	dnd	6	71
407164	4	4	6	61
407301	8	8	4	94
407438	6	dnd	4	64
407575	6	dnd	2	77
408397	6	dnd	4	90
410041	6	6	6	87
410589	8	dnd	4	74
458128	8	dnd	4	78
476897	6	6	6	92
497173	6	6	8	88
497310	6	dnd	2	30
497584	6	6	4	60
497721	8	8	8	83
498269	dnd	6	4	80
498817	8	dnd	8	86
498954	6	8	6	81
500598	8	6	6	88
501420	8	dnd	4	84
501831	8	8	8	84
501968	6	4	4	79
502379	6	4	4	87
503749	4	2	4	64
504023	4	6	6	73
504297	4	4	6	90
504434	4	2	2	60
504708	4	2	2	60
534574	6	6	6	85
534711	6	4	4	74
534848	6	4	6	96
535396	8	10	8	94
535670	8	6	4	98
535807	8	dnd	4	70
536081	6	dnd	4	82
536218	4	dnd	6	80
537040	6	8	8	90
537177	8	6	10	92
537588	10	dnd	6	86
562248	dnd	6	4	60
689932	dnd	8	4	78
	60	60	60	60

q5 responses compared in Qu.1, Qu.3			
same 18			
greater in Qu.3 10	**= 2** 9	**= 4** 1	
less in Qu.3 28	**= -2** 18	**= -4** 10	

q5 responses compared in Qu.1, Qu.2			
same 18			
greater in Qu. 2 8	**= 2** 7	**= 4** 0	**= 6** 1
less in Qu. 2 15	**= -2** 13	**= -4** 1	**= -6** 1

q5 responses compared in Qu.2, Qu.3			
same 21			
greater in Qu.3 10	**= 2** 8	**= 4** 2	
less in Qu.3 14	**= -2** 12	**= -4** 2	

Corr. between q5 of Qu.3 and final Math grades: 0.5723

dnd = did not do the questionnaire

APPENDIX 4 Description of Statistical Procedures

1- In this analysis, we are examining the effect of how mathematics and science are taught in the Liberal Arts program might affect various aspects of the attitudes that students in the program have toward these subjects. For the questions q1 through q5 on all 3 questionnaires (equivalent 10 q6 - q10 for science on the first questionnaire), we have regarded the students who answered each questionnaire as a random sample from the cohort being tested. This is justified since students answered the questionnaire voluntarily, and the factors which influenced their availability, e.g. illness, work schedule, etc., were uncontrollable and unpredictable.

Under these conditions, in order to test the null hypothesis that the course had no effect on the students attitudes toward mathematics, i.e. that $\mu_1 = \mu_2, \mu_2 = \mu_3, \mu_1 = \mu_3$ for the relevant cohort and questionnaires, if the population is normally distributed or if $n_1 + n_2 > 30$ as is always the case here, the random variable $Z = \dfrac{\overline{X_1} - \overline{X_2}}{\sqrt{\dfrac{\sigma_1^{\ 2}}{n_1} + \dfrac{\sigma_2^{\ 2}}{n_2}}}$ where $\overline{X_1}$ and $\overline{X_2}$ are the appropriate observed averages to responses to the various questions and sample variances are used to estimate the unknown population variances, is approximately normally distributed with mean $\mu_{\overline{x_1} - \overline{x_2}} = 0$ and standard deviation $\sigma_{\overline{x_1} - \overline{x_2}} = \sqrt{\dfrac{\sigma_1^{\ 2}}{n_1} + \dfrac{\sigma_2^{\ 2}}{n_2}}$.

2- In order to give a 95% confidence interval for ρ, the unknown correlation coefficient between answers to q3 on Qu.3 for all 3 mathematics cohorts and the final grade in the mathematics course, we proceeded as follows. If we let r be the sample correlation coefficient, then $Z = \frac{1}{2}\ln\left(\frac{1+r}{1-r}\right) = 1.1513\log_{10}\left(\frac{1+r}{1-r}\right)$ is approximately normally distributed with mean and standard deviation given by $\mu_z = \frac{1}{2}\ln\left(\frac{1+\rho}{1-\rho}\right) = 1.1513\log_{10}\left(\frac{1+\rho}{1-\rho}\right)$, $\sigma_z = \frac{1}{\sqrt{n-3}}$, where n represents the relevant sample size.

A 95% confidence interval for μ_z can be used to generate a 95% interval for ρ, where it can be shown that this interval (a,b) is given by

$$\left(1.1513\log\left\{\frac{1+r}{1-r}\right\} - 1.96\sigma_z, 1.1513\log\left\{\frac{1+r}{1-r}\right\} + 1.96\sigma_z\right).$$

If (a,b) mark the 95% confidence interval for μ_z then it can be shown that the corresponding confidence interval for ρ is given by $\left(\dfrac{10^{\frac{a}{1.1513}} - 1}{1 + 10^{\frac{a}{1.1513}}}, \dfrac{10^{\frac{b}{1.1513}} - 1}{1 + 10^{\frac{b}{1.1513}}}\right)$. See the Statistical Analysis, below, for the relevant calculations of the confidence intervals.

APPENDIX 4, continued **Mathematics** **TABLE 17: Statistical Analysis**

Cohort 2000: Math, N = 87 — 1st questionnaire, n = 61

	q1	q2	q3	q4	q5
Averages	5.32	5.64	9.07	7.95	5.75
Stnd. Dev.	1.69	2.35	1.33	1.15	2.06
Variance	2.85	5.51	1.78	1.33	4.24

Cohort 2000: 2nd questionnaire, n = 50

q1	q2	q3	q4	q5
5.37	5.85	8.78	7.90	4.98
2.00	2.09	1.39	1.48	2.17
3.99	4.37	1.93	2.19	4.71

Cohort 2000: 3rd questionnaire. n = 61

q1	q2	q3	q4	q5
5.69	6.10	8.82	8.26	6.26
1.90	2.17	1.26	1.37	2.32
3.60	4.71	1.58	1.88	5.37

Comparisons	q1	q2	q3	q4	q5
Z; Qu.1 vs. Qu.2	0.14	-0.50	1.13	0.19	1.91
Z; Qu.2 vs. Qu.3	0.88	0.61	0.16	1.30	**3.00**
Z; Qu.1 vs. Qu.3	1.15	1.13	-1.08	1.34	1.28

Cohort 2001: Math, N = 76 — 1st questionnaire, n = 69

	q1	q2	q3	q4	q5
Averages	6.03	6.00	8.68	7.62	6.26
Stnd. Dev.	2.04	2.37	1.94	1.59	1.98
Variance	4.18	5.61	3.77	2.54	3.93

Cohort 2001: 2nd questionnaire, n = 49

q1	q2	q3	q4	q5
6.04	6.49	8.53	8.13	5.83
1.89	2.14	1.57	1.20	1.97
3.58	4.59	2.46	1.43	3.89

Cohort 2001: 3rd questionnaire, n = 50

q1	q2	q3	q4	q5
5.96	5.96	9.08	7.84	5.64
2.27	2.30	1.01	1.61	2.55
5.14	5.30	1.01	2.59	6.48

Comparisons	q1	q2	q3	q4	q5
Z; Qu.1 vs. Qu.2	0.03	1.17	-0.45	**1.98**	-1.17
Z; Qu.2 vs. Qu.3	-0.19	-1.19	**2.07**	-1.00	-0.42
Z; Qu.1 vs. Qu.3	-0.17	-0.09	1.47	0.75	-1.45

Cohort 2002: Math, N = 79 — 1st questionnaire, n = 68

	q1	q2	q3	q4	q5
Averages	5.56	6.18	8.74	7.44	6.12
Stnd. Dev.	1.92	2.15	1.69	1.54	1.86
Variance	3.68	4.63	2.85	2.37	3.45

Cohort 2002: 2nd questionnaire, n = 45

q1	q2	q3	q4	q5
5.33	5.69	8.55	8.09	5.29
1.76	2.17	1.58	1.20	2.22
3.09	4.72	2.49	1.45	4.94

Cohort 2002: 3rd questionnaire, n = 60

q1	q2	q3	q4	q5
4.93	5.7	8.37	7.7	4.97
1.82	2.01	1.76	1.60	1.90
3.32	4.04	3.10	2.55	3.59

Comparisons

Z; Qu.1 vs. Qu.2	-0.66	-1.18	-0.61	**2.51**	**-2.07**
Z; Qu.2 vs. Qu.3	-1.79	-1.16	-1.13	0.95	**-2.79**
Z; Qu.1 vs. Qu.3	**-1.98**	-1.30	-1.25	1.03	**-3.16**

***APPENDIX 4, Continued*:** **Science**

Cohort 2000: Sci., N = 87 **1st questionnaire n = 61**

	q1	q2	q3	q4	q5
Averages	6.19	6.70	8.79	8.09	5.67
Stnd. Dev.	1.82	1.97	1.07	1.43	1.93
Variance	3.31	3.89	1.14	2.04	3.71
Comparisons					
Z; Qu.1 vs. Qu.2	-1.80	-0.83	0.16	2.13	1.02
Z; Qu.2 vs. Qu.3	0.38	0.53	0.59	-0.71	-0.61
Z; Qu.1 vs. Qu.3	-1.72	-0.33	0.77	1.76	0.43

Cohort 2000: 2nd questionnaire n = 50

q1	q2	q3	q4	q5
5.63	6.38	8.84	8.60	6.00
1.45	2.01	1.79	1.10	1.43
2.09	4.05	3.21	1.22	2.05

Cohort 2000: 3rd questionnaire n = 44

q1	q2	q3	q4	q5
5.73	6.58	9.03	8.45	5.81
1.24	1.62	1.43	0.98	1.63
1.53	2.63	2.03	0.96	2.67

Cohort 2001: Sci., N = 76 **1st questionnaire n = 69**

	q1	q2	q3	q4	q5
Averages	6.20	6.32	8.75	8.00	6.12
Stnd. Dev.	1.69	2.24	1.65	1.61	2.03
Variance	2.84	5.01	2.72	2.59	4.10
Comparisons					
Z; Qu.1 vs. Qu.2	**-3.77**	-0.72	0.28	1.35	**-2.64**
Z; Qu.2 vs. Qu.3	0.79	1.35	1.62	-1.01	1.19
Z; Qu.1 vs. Qu.3	**-2.76**	0.72	**2.04**	0.29	-1.62

Cohort 2001: 2nd questionnaire n = 49

q1	q2	q3	q4	q5
5.04	6.04	8.83	8.39	5.07
1.62	1.96	1.44	1.50	2.20
2.62	3.82	2.06	2.24	4.84

Cohort 2001: 3rd questionnaire n = 53

q1	q2	q3	q4	q5
5.32	6.60	9.24	8.08	5.56
1.79	2.03	0.98	1.46	1.78
3.20	4.12	0.96	2.12	3.15

in QU.3 at the end of the course

Discussion of Z scores

At the .05 level of significance, the critical values for Z are Z = -1.96 and Z = 1.96.
At this level of significance, statistically significant results are found at G11, F20
E 21, F37, C47, G47 C49, F30, G30, G31, C32, and G32
At the .01 level of significance, the critical values for Z are Z =-2.58 and Z = 2.58
At this level of significance, statistically significant results are found at G11, C47, G47, C49, G31 and G32

Correlational Analysis: **Correlations of responses to q5 of QU3 with Final Grades, All Cohorts, Mathematics**

	n = 61 cohort 2000	n = 50 cohort 2001	n = 60 cohort 2002
math: r =	0.6670	0.6455	0.5723
science r =	0.1055	-0.1010	

95% confidence interval for unknown population correlation coefficient, *p*, for math.

cohort 2000	cohort 2001	cohort 2002
(0.4990, 0.7867)	(0.4476, 0.7831)	(.3724, 0.7241)

q5: rating of present understanding of aims and methods of Mathematics, Science

APPENDIX 5: Course Descriptions and Program Outline

Course Description, Winter 2002

Principles of Mathematics and Logic (Liberal Arts Program): 360-124-94

0- Instructor: Ken Milkman, 5D-3, local 1567

1- The **purpose** of this course is to introduce students in the Liberal Arts program to the nature of mathematics from the point of view of the professional mathematician. We will not only describe what the professional mathematician does, but actually engage in this kind of activity within the limits of the background of the students and the time constraints of the course.

2- The course will consist of two sections: the regular classroom component (3 hours) and a laboratory component (two hours.)

A- In the regular classroom component we will begin with a unit in Logic, in which we will discuss the following cluster of concepts: argument, deductive argument, valid deductive argument, invalid deductive argument, sound deductive argument, inductive argument, good inductive argument, bad inductive argument. After claiming that the essential project of the professional mathematician is to produce proofs, we will discuss what a mathematical proof is, and identify a central version of this idea as a kind of valid deductive argument set up in a context called an axiom system. We will give examples of such systems, starting with an axiomatization of the natural numbers and elementary algebra, and either Euclidean or non-Euclidean geometry, as time permits. As well, if time allows, we will ask what place inductive reasoning has in mathematics, and take up, in this regard, elementary set theory, elementary probability theory, some descriptive statistics, and statistical inference.

B- In the laboratory component we will develop the concepts of logic taken up in the beginning of the course and discuss truth-functional logic and truth tables, truth-functional logic and natural deduction systems and, if time permits, some aspects of predicate logic.

3- A lecture/discussion method will be employed. It will be important for the student to keep up with the classroom material, and to do the homework on time. As well, students will be encouraged to display proofs they have created in class.

4- **Grading scheme:** There will be three in class exams given in the classroom component of the course, worth (cumulatively) 80% of the grade. The other 20% of the grade will be a function of assignments given in the laboratory component of the class.

5- **Text:** *Principles of Mathematics and Logic*, by Ken Milkman. Available in the bookstore.

6- **C**ollege policies on lateness to class and plagiarism will be adhered to in this course.

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LIBERAL ARTS, FALL 2001
SCIENCE: HISTORY AND METHODS
COURSE OUTLINE

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Scope and purpose: In this survey of the history and methodology of modern science we travel from the fifteenth to the twentieth century, from late medieval science and the corresponding, largely ancient Greek, picture of the world, to the development of the modern sciences, and the ideas and discoveries, disciplines and techniques, personalities and problems that distinguish them. Our main purpose is to understand how and why science has become the chief modern conception, method and model of knowledge, and what that conception is.

Aims and method: The course has several aims: to see how modern science came to have its structure of distinct, yet connected, disciplines; to understand the main ideas or conceptions of knowledge that drive science; to get familiar with major concepts, theories, and discoveries that are fundamental to science; to gain by the example of laboratory exercises an accurate grasp of the sort of work scientists do and the sort of challenges they face; to recognize the historical context - political, social, intellectual - in which science grew and which it increasingly helped shape; and within that context to become familiar with the work and lives of individuals and institutions that are important to science and its history. Of basic importance to these aims is the scientific revolution of the sixteenth and seventeenth century, and the subsequent development of our major physical and life sciences, branched into specialities.

The course proceeds in two main ways: by lectures and discussions in the class periods (3 hours\week); and by experimental or observational practice or by demonstrations or discussions on assigned reading in the laboratory periods (2 hours\week).

Office hours: A. Krishtalka: Wed., Thurs. 11:30 - 12:45 or at other times by appointment or drop-in. P. Simpson: to be announced in class.

Textbook: Peter Whitfield. *Landmarks in Western Science: from pre-history to the atomic age.* Routledge, New York 1999. (Available in the Dawson Bookstore)

Requirements and grading:

two research term papers	each 20%...	40%
two tests, in class, mid and end term	each 20%...	40%
laboratory exercises and assignments		20%

The term paper topics will be distributed and discussed in class in the second week of the term. They involve research into the life, work and contribution to science of an individual scientist.

The first term paper is due on Monday, 24 September; the second, on Monday, 5 November 2001.

The mid-term test is scheduled for Tuesday and Wednesday, 9 and 10 October 2001.

The final test is scheduled for Monday, 10 December 2001.

Attendance and course discipline: Regular attendance in classes and labs is integral to the enterprise of being a student, is important for an understanding of the material of this course, and is its own reward. There is no credit for attendance. Occasional absences may be unavoidable, but repeated or prolonged non-attendance are noted, and may lead to failure in the course.

The required assignments must be handed in on time, and the tests must be written in the scheduled times.

All course outlines draw students' attention to the College regulations on the dread duo, cheating and plagiarism. This and every course in the Liberal Arts program faithfully observe these regulations. All the assignments (other than group work) must be the individual student's own composition; term papers must acknowledge all consulted sources in a bibliography, and all borrowing of information, whether paraphrased, cited, or quoted, in proper foot or end notes.

LIBERAL ARTS PROGRAM (700.02) AT DAWSON COLLEGE: SUMMARY FOR STUDENTS

Students in Liberal Arts complete 29 courses for their D.E.C., 7 or 8 courses each term. Of the 29 courses, 18 are required; these are shown below in their order term by term (see **Core** and **Ministry** Blocks). Courses in English (4) and Humanities (3), set by the program, in French (2) and Physical Education (3), chosen by the student, are requirements - called 'Core' - common to all programs.

In each term students have options within the program: they choose a total of 6 courses from the disciplines in the Ministry Block or the College Block (see reverse) to fulfill graduation requirements and personal interests; as well, they choose the required 3 Physical Education and 2 French courses which are part of Core.

LIBERAL ARTS CORE and MINISTRY BLOCK: 18 courses

	term 1	term 2	term 3	term 4
Core	**English 603-101-04** Writing and Rhetoric **Humanities 345-102-03** Medieval Civilization	**English 603-102-04** Poetry	**English 603-103-04** Drama **Humanities 345-103-04** Theories of Knowledge	**English 603-BXE-04** the Novel **Humanities 345-BXH-94** Law and Morality
Ministry	**Philosophy 340-910-94** Ancient Philosophy **Classics 332-115-94** Græco-Roman Civilization **Religion 370-121-94** Sacred Writings **300-302-94** Research Methods	**Philosophy 340-912-94** Modern Philosophy **History 330-101-94** Renaissance to French Rev. **Art History 520-903-94** Renaissance to Baroque **360-124-94** Principles of Mathematics and Logic	**History 330-910-91 *(College Block)*** 19th and 20th Century World **360-125-94** Science: History and Methodology	**360-126-94** Integrative Seminar

1. The first three digit group in any course number denotes its discipline; the second its content; the third, the class hours or the date of its introduction : e.g., 603-101-04 denotes English: Writing and Rhetoric, 4 hours/week. (For the purposes of telephone registration, each class of a course in the *College Timetable* is assigned another unique numeric code to be dialled.)

2. The *College Timetable*, distributed before Registration each term, allows students to devise alternative schedules. Liberal Arts students fit their other Core (French and Physical Education) courses, and their desired option courses (from the College Block) around the required Liberal Arts courses. Since space in their required courses is reserved for them, Liberal Arts students should register first in their other courses, making sure that their choices fit within their Liberal Arts timetable. Each term, students must take care to register in all of their required courses in the Core and Ministry Blocks for that term. Students must not choose optional courses with the same course numbers as those of their required courses.

LIBERAL ARTS COLLEGE BLOCK: choose a total of 6 courses over 4 terms

Courses in the Ministry Block and the College Block, below, are organized in discipline groups. Liberal Arts students may take courses from (or 'open') a maximum of six discipline groups. The Ministry Block 'opens' three discipline groups: History, Classics; Philosophy; and Art History, Religion. Students may 'open' one to three more, and may take a maximum of 4 courses in any single discipline group.

discipline group	discipline numbers
Ancient Languages:	
Latin, Greek	615
Modern Languages:	
Spanish	607
Italian	608
German	609
Russian	610
Hebrew	611
Yiddish, Arabic	612, 616
and other languages: all as available	
Geography, Anthropology	320, 381
History, Classics	330, 332
Psychology, Sociology	350, 387

discipline group	discipline numbers
Economics, Political Science	383, 385
Philosophy	340
English Literature, French Literature	603, 602
Fine Arts, Religion	510, 511, 520, 370
Performing Arts: Cinema, Music, Theatre	530, 550, 560
Mathematics, Computer Languages	201, 420
Sciences:	
Biology	101
Chemistry	202
Physics	203
Geology	205

October 2001

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Liberal Arts Program and Abilities May 2001

All college programs emphasize among other things the abilities (or *compétences*) which students acquire as they master the subject matter of their courses. Attention to abilities is an ancient, traditional, essential and inescapable aspect of education. In the modern college and university, and in Liberal Arts, courses in many disciplines unfold - and help students develop - a variety of intellectual abilities: by readings, assignments, and methods of teaching and assessment. The abilities cannot be taught, learned or evaluated on their own, separated from content. Only in our thinking about education can we abstract abilities from subject matter. The processes of teaching, learning and using what we learn unite content and abilities inextricably. Students acquire both by their own active effort of study and practice, and then can apply both in their further studies, employment and leisure.

There are many ways of stating, subdividing and organizing the abilities acquired in different disciplines. The arrangement made here has one practical aim: to tell students plainly the abilities that the Liberal Arts Program expects they should develop or attain through their four terms of college. We organize the many types of abilities under four general headings, as follows: students are expected to develop and demonstrate the capacity for

- (A) critical thought and reflection;
- (B) personal responsibility and ethical discernment;
- (C) cogent, well formed oral and written expression;
- (D) informed aesthetic responses.

The order displayed above is meant to make discussion easy, and is not a ranking by importance. The same should be understood of the unpacking of each ability below into components. Indeed, the four abilities and their components (however conceived or phrased) run together, closely linked and mutually dependent, in all our courses. This is an important fact to remember as each is stated separately.

A. **critical thought and reflection**

The disciplines and the courses taught in the Liberal Arts program work to develop in students the habits of critical thought and reflection, applied to what they are studying. This means, first

(A.1) that students recognize how knowledge is organized: how it is divided into disciplines, how this demarcation of areas of knowledge has itself shifted and changed, and what the characteristic viewpoints, problems and strategies of the disciplines are; and second

(A.2) that students recognize, assess, criticize and learn to formulate clearly valid arguments and defensible judgements within these areas of knowledge; and in so doing, learn and use the requisite skills of research and documentation, especially the uses and resources of the research library; and third,

A.3) that by the critical assessment of their readings, and of the opinions they hear in their classes, students see the relations between assumptions, theory, evidence and proof in the subjects they study, and demonstrate their grasp of these relations in their own written or oral presentations.

B. **personal responsibility and ethical discernment**

By studying the subject matter of the program, by pursuing the questions it raises for them, and by doing the work it asks of them, students cultivate as well the necessary ethical dimension of being educated, in at least two senses: to discern and be aware of the ethical aspects of what they study, and to show personal responsibility in applying high ethical standards to the creation and management of their own work. This means, first

(B.1) that students identify, and learn to analyze and discuss with clarity the ethical questions raised by and within various areas of knowledge, in what the latter either demonstrate or assume; and second

(B.2) that students understand the ethical standards of good scholarly and scientific work, realize the importance and characteristics of intellectual integrity, and demonstrate it in their own work, by fulfilling its practical requirements; and third

(B.3) that students learn to arrange their time, tasks and effort, in order to plan and accomplish their work in good time, individually or with others.

C. **cogent, well formed oral and written expression**

By the example and analysis of their reading, and by means of their course work, oral and written, students develop the art of exercising the language to convey their knowledge and ideas with accuracy, clarity and precision. This means, first

(C.1) that orally or in writing students analyze, compare and sum up their reading on assigned subjects; they define and discuss the questions and conclusions which they and others draw from these works, and they state their critical evaluations or judgements; and second,

(C.2) that students develop the habit of editing critically and revising the grammar, diction, syntax, spelling and organization of their own oral and written work to make it convey what they mean, and fit the subject in form and style; and third,

(C.3) that students develop their powers of research, judgement and expression sufficiently to define and accomplish complex written projects.

D. **informed aesthetic responses**

Virtually every aspect of our lives engages our aesthetic sense; it informs understanding and expression, and is honed by them. In the educated person the aesthetic sense is present to the conscious mind. As do many educational traditions, the Liberal Arts encourage students to cultivate and educate their aesthetic awareness and appreciation. This means, first,

(D.1) that students acquire and exercise the vocabulary, language and concepts with which to state clearly their personal, or analytical, or critical response to a created work; and second,

(D.2) that students distinguish those properties of a created work which shape its meaning and impact, which help identify and explain it (relate it for comparison to other works in similar or analogous media, subject areas, styles or periods), and which may be the basis of judging its use of its medium; and third,

(D.3) that students show a grasp of the context of ideas or associations which induce or influence their regard of a created work, and form their responses cogently within a critical framework or theory.

Appendix 6: List of Tables

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