HIGH SCHOOL MATHEMATICS IN ATLANTIC CANADA

A Report Prepared for the Canadian School Mathematics Forum Montreal, May 16–18, 2003

1 A New Curriculum

Atlantic Canada is starting to feel the effects of a new mathematics curriculum which, except for specific course syllabi and distribution of material, is common to the region. For example, New Brunswick has introduced four courses—two in Grade 11, and two in Grade 12—which correspond to three courses in Nova Scotia and Newfoundland. (The four NB courses use approximately 10% more time than the three courses in NS and NL.) New Brunswick, Nova Scotia and Newfoundland are making use of a new set of textbooks. While Prince Edward Island has also adopted the common curriculum, it made a decision in June 1998 to choose its own resources and to develop its own process for implementation, separately from the other provinces.

The curriculum is being introduced, province by province, at varying rates. The first partial cohort of students to have experienced the full four years of the new programme arrived at universities in Nova Scotia last Fall, 2002 (a minority of that year's intake). The first full cohort from the new curriculum will be in Fall 2003 (NS, NL, PEI). It will be the Fall of 2004 before New Brunswick universities meet the first full cohort of students from the new curriculum.

Based upon the 1989 "standards" document of the National Council of Teachers of Mathematics,[1] the new curriculum has caused quite a stir throughout the region, especially within the university system. In fact, Atlantic Deans were sufficiently concerned about the potential effects of university level students with weakened mathematics skills that they appealed to the Atlantic Provinces Council of the Sciences (APICS)[2] for a report. Such a report was commissioned by Dr. Roger Gordon, APICS Chair (and Dean of Science at the University of Prince Edward Island), and released in the spring of 2002.[3] Much of that report forms the basis of what appears here.

[1] http://standards.nctm.org/Previous/CurrEvStds/
[2] http://www.math.dal.ca/~apics/
[3] http://www.math.mun.ca/~apics

2 History

The new mathematics curriculum in Atlantic Canada was designed by teams of educators with coordination provided by the Atlantic Provinces Education Foundation (APEF). This is a consortium which began as the Maritime Provinces Education Foundation (MPEF) in 1985 and expanded to include Newfoundland in 1995. The APEF is funded by the governments of the Atlantic Provinces to manage joint education projects, and acts on directions from the provincial authorities. The goals are to develop a uniform school standard across the region, to unify resources with the hope of achieving some efficiency in costs to the provinces, to bring together more curriculum development expertise, and to facilitate student movement between provinces.

APEF offices (located in Halifax) established a working group which delegated lead responsibility for the primary/elementary curriculum to New Brunswick, for the intermediate curriculum to Newfoundland and, for the high school curriculum, to Nova Scotia. While existing textbook series were adopted for use at the primary/elementary and middle school/junior high levels, the Atlantic Provinces made the decision to commission the writing of new texts for grades 10–12. (We discuss the ramifications of this unusual decision at length below.) As syllabi were developed, publishers were invited to submit proposals for matching text and resource development. International Thomson Publishing was awarded this work and struck author teams for two text series, *Mathematical Modeling* for the "advanced " courses (post-secondary-intending students who expect to take some mathematics at university) *Constructing Mathematics* for the "academic" courses (non-post-secondary-intending students, and students who will follow post-secondary programs not requiring the study of mathematics). There is a teacher resource binder with each text.

3 Implementation and Piloting

Historically, the process for piloting new curricula involved adopting existing texts which best met the needs of the courses while pilot teachers tried to find appropriate supplementary resource materials. The pilot process for APEF was dramatically different, however. Not only were syllabi in **draft form** for most of the process, but so were the texts. In most cases, it could be argued, the pilot teachers were in fact rough copy editors, an experience which lasted up to three years for some teachers, and their students.

Repercussions of this new process on several fronts could have been anticipated. The first generation of graduates would likely not be representative of future students, as materials were dramatically altered. Teachers would likely struggle to complete courses as author teams and publishers refined time lines and approaches throughout the pilot process. In many cases, texts were not ready for general distribution until late in the summer, just a week or two before they were required, so advance preparation by teachers was impossible.

Combined with a dramatic shift in approach and a marked shift in emphasis (from more traditional algebra with significant practice to investigative processes and a statistics theme), the need to become familiar with a substantial bundle of teachers' resource material, and with limited professional development time, it is not surprising that the first few years of implementation produced the full gamut of reactions from teachers: from enthusiastic excitement to extreme frustration. Many pilot teachers complained that they could not complete the material – using the suggested teaching methods – in the time allocated, and students from piloting schools have not fared well in university mathematics. During the Fall 2001 semester, Memorial University tracked the progress of 55 first year calculus students all of whom had followed the new curriculum. Nearly sixty percent of these students either failed or withdrew during the semester.

4 Approach

Under the new curriculum, substantial class time once invested in teacher-led discussion is now invested in activities. Much of the time once spent in gaining efficiency via practice sets is now spent answering a few germane questions designed to distill concepts from the activities. Student engagement in class time has never been more important. It is difficult to learn just by reading the texts; the student must also "experience" the material and generate a personalized set of learnings called "Notes" which become their core study material, rather than the text itself. In particular, students who miss class are at a severe disadvantage: they cannot catch up by referring to the text alone.

Of course, this approach puts pressure on parents, tutors and friends. At first glance, there is little in the new textbooks that looks familiar or affords a handhold into the material. As one teacher recently put it, "it's as if the signposts are missing." When you look deeply enough and know what you are looking for, you can see where the development is going; but none of this is clear until you have carefully worked a unit.

The Atlantic Canada Curriculum is intimately tied to the graphing calculator and manipulative technology. Literacy with the Texas Instruments TI-8* series of graphing calculator is necessary, as are skills with manipulatives (such as algebra tiles), probability simulations, and Internet research.

5 The Textbooks

The APEF Nelson textbooks used in New Brunswick, Newfoundland and Nova Scotia are quite unlike those to which most people are probably accustomed. Most of the material is expository, not example-driven. The texts provoke discovery by asking questions like "What do you notice?", "What is your conclusion?" More like lab manuals than textbooks, they do not seem friendly and are not particularly useful for last minute cramming (which may be a good feature). The answers to relatively few exercises are in the back. (The first book in the series, *Mathematical Modeling I*, has no answers in the back at all.[4]) The teacher facilitates students' discovery of essentials from each "Investigation" and "Focus"[5], while students generate notes, summarizing the material. Practice sets are limited, though additional practice and some summary notes appear at the end of each chapter.

The texts are difficult to read unless in conjunction with the accompanying "Teacher Resource" documents. This places parents, would-be tutors, mentors, and the students themselves at a definite disadvantage, since they don't have access to the Teacher Resources. Moreover, the better students who like to work independently and would otherwise proceed on their own at a faster pace are unable to do so.

To say that the books in the *Mathematical Modeling* series (those written for the "advanced" stream, post-secondary-intending students) have created controversy is understating the case. In the spring of 2002, David Hamilton, a statistician at Dalhousie University, became alarmed at some things he saw in *Mathematical Modeling* 2 and contacted the mathematics consultant for the Nova Scotia Department of Education. After some discussion, Dr. Hamilton offered to provide a written report, describing his concerns about Chapter 5. At about the same time, Dr. Robert Dawson from Saint Mary's University, Halifax, and Dr. Maureen Tingley of the University of New Brunswick, Fredericton, were discovering and recording errors in the series. Eventually, these three individuals authored a report which was released as a report of APICS on November 1, 2002. The report is available at

`www.math.mun.ca/~apics`.

We highlight here just some of the errors of fact, explanation, and emphasis, and some of the potential sources of confusion, which have been found.

- In compliance with Système Internationale standards, the books use spaces, rather than commas, to separate groups of three digits in numbers. This is very uncommon in North America, however, and expressions like "sin 282 239x" (Book 2, p. 123) seem rather bizarre.
- There are factoring exercises which **require** solution via diagrams involving algebra tiles.
- The definition of "outlier" would flag 5% of any data set as outliers.
- The equals sign is abused repeatedly with expressions such as "Outlier = [mean] + 2[SD]" and statements like "$\sin 105° = 0.9659$."
- The authors confuse marginal cost with average cost.

[4] Newfoundland has produced an answer booklet, available on the web.

[5] "Investigations" are student activities and / or discussions designed to develop a concept. "Foci" are teacher-lead topics not unlike traditional teaching.

- The authors blur the distinction between equation and function.
- To quote the above mentioned errata document, "Chapter 5 of *Mathematical Modeling* 2 is extremely poorly written, to the point where it should probably never be used in the classroom. ...just about every topic covered involves fundamental misconceptions." (In light of the APICS report, this chapter was removed from the curriculum for the 2002-03 academic year.)
- Calculators are used to justify the convergence of series.
- It is asserted that all infinite sets have the same cardinality, and this is denoted $\aleph_0$.
- Several supposed real-world examples use unrealistic numerical values.
- Presentation of important ideas is often clouded by vague wording, or poor grammar.

The appearance of problematic textbooks did not come without warnings. During planning stages of both the curriculum and the text books, Departments of Education throughout the region received extensive feedback from a few university professors whose opinions had been solicited. Most of this feedback was ignored, possibly because academics from university departments of mathematics and statistics form a small minority on all provincial advisory committees (if they are included at all).[6]

In February 2003, the provinces were provided with the draft of an errata document for the *Constructing Mathematics* series. This document includes several extensive discussions of material that the texts treat poorly.

6 Reaction

Whether the new curriculum will prepare students to participate with confidence in a rapidly changing world, and prepare some students for post-secondary education, will not be known for years. This of course has never stopped people from voicing their opinions!

6.1 Pros

Proponents of the new curriculum feel strongly that it is based on sound pedagogical principles and that the new approach should be given a chance. Its attempt to present mathematics as a subject in which people discover things,[7] as well as memorizing techniques, are praiseworthy.

The new curriculum is also designed to reflect the pedagogical theory that new learning is more likely to be retained if it is meaningful than if it is not. The new curriculum places

[6] The APICS web site `http://www.math.mun.ca/~apics/` documents some attempts to alert high-school educators to the concerns of an important group of professional mathematicians and statisticians.

[7] Curriculum documents use the phrase "construct new understandings" and "construct knowledge".

an increased focus on problem solving, reasoning and communication, all skills on which society places a higher value now than ever before. When presented clearly and correctly, the content of the new curriculum is likely to be more interesting and exciting to students. (Early classroom reports bear this out.) While execution has been flawed, the basic goal of teaching (in the words of an official with the Nova Scotia Department of Education) "enough statistics to enable a student to read the newspaper intelligently" is a fine one, both worthwhile and realistic.

Proponents also stress that the basic algebra, trigonometry, geometry, and theory of functions, topics in which universities want students to become proficient, **are** covered in the new curriculum and in a way that will improve students' understanding of them.

6.2 Cons

University professors were involved in providing feedback to the development of the new mathematics curriculum and commented at length on drafts of textbooks. Some of these people, however, felt they were ignored and that their considerable efforts were made largely in vain. Concerns about lack of precision and care in the preparation of the materials, as well as errors in both theory and illustrations, were simply not acknowledged, let alone addressed.

More recently, university teachers have commented on two aspects of the new curriculum: content and method of delivery.

With reference to method of delivery, surely good teachers have used investigations (to varying degrees) for centuries, if not millenia. But time does not permit all topics to be discovered. The associated decrease in time spent honing algebraic skills is cause for concern among university teachers who see, year after year, that poor algebraic skills are the root cause of many failing grades in first-year mathematics. From the perspective of many, the curriculum attaches far too little importance, at all grade levels, to good old-fashioned practice.

With reference to content, there is an over-emphasis on topics that used to be reserved for universities, at the expense of what have always been deemed core school topics, essential for success in higher mathematics. University teachers are also concerned that too much core pre-calculus material has been delayed until the final three semesters of high school, leaving insufficient time for students to assimilate new ideas. Errata documents for the new texts (mentioned above) point to serious conceptual errors made by those entrusted with implementation of the new curriculum.

The new curriculum encourages (even more than the old) the use of calculators and manipulatives. Judicious use of both may help some students, but they can also hinder the ability to perform certain mathematical tasks automatically. There are places where calculator use is encouraged (justifiably), places where the calculator is (rightly) not employed for sections at a time, and some places where calculators are used unnecessarily.

The public perception that mathematics cannot be done without a calculator is a sign that mathematicians and mathematics educators have done a poor job explaining the difference between mathematics and arithmetic.

7 Provincial Perspectives

The Departments of Education of NB, NS and NL commissioned an independent review of the comments pertinent to Chapter 5 of *Mathematical Modeling 2* in the APICS errata document[8]. This report has been received by the provincial Departments of Education, which have since reduced the scope of material to be covered from the chapter (in the short term, at least).

New Brunswick has prepared and circulated its own (much edited) version of the errata for *Mathematical Modeling* texts 1 – 3, while Nova Scotia and Newfoundland are following suit.

7.1 New Brunswick

The New Brunswick Department of Education has publicly expressed its concern that many NB mathematics teachers have not been prepared to teach the old curriculum, and that many more are ill-equipped for the new curriculum. In response, the province has introduced a mentor program for teachers.

As has been mentioned, the implementation of the new curriculum has varied from province to province. As Table 1 shows, the ordering of material in New Brunswick must be a logistical nightmare, heightened by the fact that there are no spare copies of textbooks. (What happens when one class is ready to swap texts, but the other class is not?) Table 1 also underscores a concern that this new curriculum does **not** build on knowledge, to the depth required by "advanced" students: too many topics are interchangeable.

Under the old curriculum, New Brunswick had a province-wide examination of Grade 11 mathematics, contributing 30% of the final mark in a course required for high school graduation. The new curriculum requires less mathematics for graduation, and the province-wide assessment has moved to the first course **not** required for graduation. The last course required for graduation (Math 111/2A) includes an "independent study" unit (2), and an overly ambitious unit on statistics (1) that is full of errors. So the decrease in mathematics required for graduation is even greater than it would appear. Material required by students going on to mathematically-intensive university programs is crammed into the last three semesters of high school, following three relatively slow terms, in which those students are at risk of becoming mathematically lazy.

The University of New Brunswick is carefully tracking performance of the last few intakes of students taught under the old curriculum, and will compare performance of cohorts taught under the new.

[8] `http://www.math.mun.ca/~apics/`

Course	Unit	Text	Chapter
Math 111/2 A	1	MM2	5 (omitted 2002 - 2003)
	2	MM2	2
	3	MM3	5
	4	MM3	4
Math 111/2 B	1	MM3	1
	2	MM3	2
	3	MM3	3
	4	MM2	6
Math 121/2	1	MM2	3
	2	MM2	4
	3	MM4	parts of 3 and 4
	4	MM2	1

Table 1: In New Brunswick, *Mathematical Modeling* textbooks do not match courses.

The NB Department of Education has reminded teachers to focus on student achievement of the outcomes in the curriculum and that the use, from time to time, of other resources towards that end is certainly appropriate. (i.e., NB has notified teachers that some sections of the new textbooks overemphasize use of the graphing calculator, that time does not allow for all topics to be covered using the methods outlined in the new textbooks, and that teachers may use some of the more classical problems from the old textbooks.)

The New Brunswick government recently requested an independent review of the anglophone school system.[9] An excerpt from the report:

> The New Brunswick system rarely describes itself as responsible for learning, but often describes itself as nurturing and protective of children. The description reflects social values and beliefs that provide an important foundation for a respectful and caring community.
>
> Unfortunately, in many New Brunswick schools, these values have been translated into classroom structures that serve the learning needs of few.

[9]Dated April 24, 2002, the full Scraba report can be found at `http://www.nbta.ca/nbta11.html`.

7.2 Newfoundland

For many years, there have been two streams of mathematics in the high schools in Newfoundland, "academic" and "advanced". From the perspective of the university, students from the *academic* stream have always been weak and certainly not ready for the standard first year university calculus course. In the mid 1980s, to cope with and assist this group, the Department of Mathematics and Statistics at Memorial University created a two-course sequence which covered the basics of differential calculus with some supplementary material on exponentials, logarithms, trigonometry and functions—high school material by anybody's standards.

In the late 1980s, a "mathematics skill inventory (MSI)" was introduced to give the Department a way to measure skills and capabilities of incoming students. Eventually, it became possible to detect with considerable accuracy students likely unable to cope with first year calculus. At this point, the MSI became the MPT, the "Mathematics Placement Test" which is now required of at least a thousand entering students every year. Without a mark of 55/100, students are not permitted to register for even a pre-calculus course.

The old *advanced* high school stream was excellent. The MPT was never required of students from this stream because we knew they would perform well in their university courses. These courses have been replaced.

Teachers have complained about the lack of in-service and other preparation for a curriculum which is very different from anything they have seen before. Both students and teachers in Newfoundland are unhappy with the lack of practice time and the de-emphasis on basic skills. Getting the correct answer now seems less important than the "experience" gained working on the problem and the overall "comfort level" with the material. Many people have severe doubts about the discovery approach to learning. As the author of an opinion piece which appeared in the St. John's Telegram not so long ago (a high school teacher) put it, would you teach a person to swim by throwing her in a pool and hoping she would discover on her own how to survive?

One issue in Newfoundland which created a stir in the spring of 2002 dealt with Math 3205, the third course in the new advanced stream. Many teachers in the province were unable to complete the syllabus (the discovery approach takes a lot of time), so the Minister of Education cancelled the scheduled public exam out of "fairness" to the students, who were evaluated by their schools alone. Many people argued that this was folly and would only serve to give graduating students (and their parents) a false sense of their preparedness for university. There have always been significant differences between high school and first-year marks, another reason for the Mathematics Placement Test.

In Newfoundland, an additional course (Mathematics 3103) has been developed for academic stream students. This course helps to fill possible gaps in algebra between the academic set of courses and university preparedness. It addresses some basic skill deficiencies in both numeracy and algebra, with particular consideration given to aspects of the MUN Mathematics Placement Test. Teachers report that there is a marked difference in students' abilities to deal with Mathematics 3204 when they are registered for Mathematics 3103 at the same time. Some teachers plan to deliver this course in grade 11, believing that the background knowledge will be valuable for students before going into their final year.

7.3 Nova Scotia

Nova Scotia is the first province to have a full cohort using at least part of the *Mathematical Modeling* series. Some of these students entered university in the fall of 2002. There seems to be general agreement that they are not as well prepared for first-year calculus as was the case in previous years. At Saint Mary's and UCCB, for instance, where a placement test is administered to students wishing to take first-year calculus, the proportion of students passing the placement test dropped significantly from last year. Most of these students are from Nova Scotia.

It must be stressed that performance has been dropping for some years, so that the new curriculum cannot be the only factor involved. For instance, it is reported that many students have used a different text for Precalculus 12, and in many cases also for Advanced Math 11 and 12, switching curricula in midstream. It is to be hoped that these problems are "growing pains" that will disappear over the next year or so.

It is also clear that the problem begins before high school. Recently released results on the provincial Grade 8 assessment test showed an average of 32%. Since test scores did not contribute to students' year-end grades, this low average probably does not reflect true average ability. On the other hand, it is difficult to share the optimistic view, widely quoted in the media, that these results do not show any real problem. Nova Scotia has scheduled Grade 12 Examinations in Mathematics to begin in January 2004, with the exam contributing 30% of a student's final mark.

It is well-known that many mathematics classes across the province are being taught by teachers with little formal training in mathematics. The *Mathematical Modeling* and *Constructing Mathematics* series, with their many errors, unusual topics, and idiosyncratic methods, require more mathematical background from the teacher than do most texts. Regulations due to come into effect in 2005 will be a first step towards rectifying this, requiring all first teaching assignments to be in a subject that the holder is certified to teach. However, this does not apply to any subsequent assignment.

This problem is, of course, largely due to the shortage of properly trained teachers. The Nova Scotian government has identified and addressed the shortage of qualified mathematics teachers in a report [10] dated December 2001. An aspect of the Nova Scotian teacher certification process (possibly also found elsewhere) that may contribute to the shortage of highly trained personnel is the fact that no recognition (in terms of license grade) is given for qualifications in teachable subjects above the minimum but below a postgraduate degree. A beginning teacher with an honours degree in a teachable subject gets the same Initial Teacher's Certificate as a teacher with a concentration within a three-year degree.

If teachers do not have more than the minimum training in mathematics before they start the B.Ed., they will have a hard time obtaining it later. An M.Sc. in mathematics is a two-year program, the courses are usually taught during "traditional" hours, and a teacher with a minor or concentration in mathematics will not have the prerequisites to enter. The M.Ed. - a one-year program, scheduled for working teachers, and with a two-year B.Ed. as the entrance requirement - is far more accessible.

Obviously, the first and greatest need is for more teachers with *some* mathematical training. However, as the recent textbook problems show, there is also a need for more teachers within the system who are highly trained *in mathematics and related subjects*. The government, the teachers' union, and the universities must find ways to make this happen.

7.4 Prince Edward Island

On Prince Edward Island, approximately 50% of high school students plan to attend university, 20% plan to attend college and 30% plan to enter the work force after high school graduation.[11] The PEI Department of Education, in partnership with mathematics high school teachers, UPEI and Holland College, developed courses that best filled the needs of PEI students. The provincial Mathematics Committee includes a member from the Department of Mathematics at each of UPEI and Holland College, and a teacher from every senior high school in the province. Teachers have a direct influence on the thrust of the various courses.

[10] Report of the EFC Subcommittee on Teacher Demand and Supply

[11] See, for example, *Preparation and Expectations: a Survey of Island Grade 12 Students—2001* prepared by the P.E.I. Department of Education.

While Prince Edward Island is implementing a mathematics curriculum based on the APEF foundation document, it made a decision in June 1998 to choose its own resources and develop its own process for implementing the curriculum, separately from the other provinces. The APEF courses on Prince Edward Island use textbooks published by McGraw-Hill and Addison Wesley for use in Western Canada[12] and combine a balance of traditional and discovery based experiences to achieve the curriculum outcomes in each course. Depending on the course, use of graphing calculators can account for anywhere from 10% to 30% of classroom activities. Graphing calculators are used to enhance and not replace basic mathematical skills. They allow students to explore topics, such as polynomial functions of degree three or more, which were previously too cumbersome to investigate.

While the APEF curriculum calls for four academic courses, teachers in PEI felt that five were needed to cover the curriculum. The McGraw-Hill and Addison Wesley academic math texts have not generated the same controversy as the Nelson texts in the other provinces. PEI is following a similar academic curriculum as its sister Atlantic provinces and is experiencing a successful implementation process. Teachers and students are enjoying the new curriculum, and teachers see a marked improvement in student skills in working with functions and transformations.

8 Authorship

While the principal authors are faculty at Atlantic Universities, a number of people contributed information and/or comments which have been used in the writing of this report, including

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[12] Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories, Yukon and Nunavut—see `http://www.learning.gov.ab.ca/news/1996nr/june96/nr-fourwpnr.asp` for more details on what these jurisdictions are doing

Robert Dawson is Chair of the Department of Mathematics and Computing Science at St. Mary's University, Halifax. He has a PhD in Mathematics (Cambridge) and has edited an APICS booklet, *Preparing for University Calculus*[13] to inform students of the skills they should have before entering a university calculus course.

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[13] `http://www.math.mun.ca/~apics`

APPENDIX

Courses and Syllabi

While there is some variation in course content, organization of material, and pattern of delivery from province to province, in general terms the new curriculum has two streams, an “advanced” for students bound for post-secondary education and an “academic” stream for the others. Content is modular rather than spiral.

Content of the academic stream is similar to that of the first three courses in the advanced stream, though topics are not treated as deeply nor are the goals as sophisticated as they are for students in the advanced stream.

A statistics theme occupies part of the first three courses. The fourth course is essentially pre-calculus with some calculus. One concern, under current course and unit alignment for example, is that a student sees nearly all precalculus trigonometry in just the second course.

Course 1

- Data management: a statistics unit which includes topics like lines of best fit which are part of some second year university courses.[14]
- Networks and matrices: This includes network problems using graphs and digraphs, adjacency matrices and matrix multiplication, topics which appear in third year at Memorial University, for instance.
- Patterns, relations, equations and predictions: students solve linear equations graphically and algebraically.
- Modeling functional relationships: the concept of function.
- How far? How tall? How steep? Right angle trigonometry.
- The geometry of packaging: relationships between volume and surface area, for containers with various shapes.
- Linear programming: includes solution of systems of equations and inequalities involving two unknowns, a standard university business course topic

Course 2

- Equations in 3-space, algebra: 3-space, the solution of systems of equations using inverse matrices, standard university material.
- Independent study unit: students explore a mathematical topic independently and make presentations to the class.
- Trigonometry 1: periodic behaviour, the sine function.
- Trigonometry 2: the algebraic solution of trigonometric equations, trigonometric identities.
- Statistics: using survey results to draw inferences about a population, confidence intervals, hypothesis testing, χ-square tests, all university-level material.
- Applications of trigonometry: the laws of sines and cosines, the area of a triangle.

Course 3

- Quadratics: arithmetic and geometric sequences, regression, the quadratic formula.
- Rate of change: students discover how the shape of a graph indicates change and how the slope of the tangent relates to change.
- Exponentials: including laws of exponents and the logarithm.
- Circle geometry: transformational, Euclidean and coordinate geometry, slopes of parallel and perpendicular lines, the equations of circles and ellipses.