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A Study of the Reform of Mathematics Education for the Upper Secondary School in Japan[1]

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The COM curriculum provides first a core of mathematics for all students, and then offers opportunities for students to enter different streams of mathematics studies. The flexible curriculum (COM) is certainly welcome as it focuses on a transition from concrete to conceptual mathematics and on sequentially learning the power of mathematical language and symbols from simple to complex. This approach emphasizes the use of computers in mathematics education in the upper secondary grades. In Mathematics A, one unit is developed to computer operation, flow charts and programming, and computation using the computer. In mathematics B, a chapter addresses algorithms and the computer where students learn the functions of computers, as well as programs of various algorithms. Mathematics C allots a chapter for numerical computation in which approximating solutions for equations, numerical integration, mensuration by parts, and approximation of integrals. But, unfortunately, they do not have any plan for the cooperation study.

I. INTRODUCTION

I will begin with a brief introduction of the Japanese system of education and a description of the reform of mathematics education at the upper secondary level in Japan. Japanese school operate on an elementary-middle-high-college (6-3-3-4) system. Before elementary school there is kindergarten for one to three years followed by compulsory elementary and lower secondary school. After upper secondary school there are two years of junior college and special training schools. In 1986 enrollment in upper secondary school was 94.2% and in colleges and universities 34%. These percentages increased compared with those in 1970 — 79.9% for upper secondary school and 18.7% for colleges and universities (Fujita 1987).

Advancement to upper secondary school, college and university is based on an entrance examination. These examinations for prestigious universities are very difficult,

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and mathematics is one of the key subjects.

In 1984 the Japanese government established the Nation Council on Educational Reform as an advisory body to the prime minister to propose relevant reform of various government policies and practices related to education. They published their final report in August 1987. The report emphasized on individuality, transition to life long education, internationalization, and an information-oriented society. Revision of the school curriculum was undertaken by the Ministry of Education, Science and Culture beginning in 1985. The Course of Study has been revised once every ten years. The current Course of Study was put in place in 1980 for elementary schools; in 1981 for the lower secondary schools, and in 1982 for the upper secondary schools. The new Course of Study for the upper secondary level was revised by the Ministry of Education in 1989, and will be put into effect in 1994. It will control Japan school mathematics for some years.

II. The Reform of Mathematics Education

As mentioned above, the Japanese mathematics curriculum for upper secondary schools has been revised recently. The philosophy of this reform stems from

1) the high rate of advancement for students in the upper secondary level,
2) the polarization of the flow of students, and
3) the requirements of the information age.

The objectives of the new upper secondary mathematics curriculum are to help students deepen their understanding of basic mathematical concepts, principles, and laws to deal mathematically with various phenomena, and to appreciate this way of viewing and thinking, and thereby to foster attitudes which encourage the use of such abilities. According to Fujita et al. (1986), "the new mathematics curriculum for upper secondary schools is composed of a "core" and "option modules." The core of upper secondary school mathematics must be mastered by all students. The options modules are classified into three types: remedial options, side options, and advanced options. Remedial options are for students whose preparation in lower secondary school is inadequate for upper secondary school mathematics. Side options are for brighter students learning the core. They can study some option modules chosen in conformity with their abilities and aspirations, in order to enrich the core. Advanced options are option modules that include advanced topics to be learned by high-level students and/or students planning to enter science and technology streams after completing their core study. Depending on the level of the class and the school, the same option module can be used either as a side option or as an advanced option."

The new Course of Study strongly recommends that teachers should make use of educational technology such as computers to improve the effectiveness of instruction and that in teaching computation, they should make appropriate use of calculators to improve the effectiveness of learning.

The new upper secondary school mathematics is composed of the following six courses (the numbers in parentheses indicate the standard number of credits, equal to the number of class hours devoted to each course per week, where one class hour is 50minutes): Mathematics I (4), Mathematics II (3), Mathematics III (3), Mathematics A (2), Mathematics B (2), and Mathematics C (2).

An important feature of the Course of Study is that the various branches of mathematics (e.g., algebra, geometry) are integrated and taught as integrated parts. All students study Mathematics I in the first year of upper secondary school; the other subjects are optional. Mathematics I and II are designed to be the common core for all college-bound students and for students who will need mathematics in their future careers. Mathematics III is the core for students who plan to enter the scientific stream or who want to study more mathematics. On the other hand, Mathematics A, B, and C are optional, each school will select their content from the Course of Study in accordance with its students' aptitudes and interests.

The new mathematics courses for the upper secondary school curriculum are outlined below,

Mathematics I: Objectives of Mathematics I are to help students understand quadratic functions, geometrical figures and mensuration, treatment of numbers of cases and probability; through consideration of concrete phenomena, and to encourage them to master basic knowledge and skills, to develop their appreciation of the significance of the mathematical way of viewing and thinking. The content of "Mathematics I" is;

1. Quadratic functions: quadratic functions and their graphs, and the variation of values in quadratic functions;
2. Geometrical figures and mensuration: trigonometric ratios (sine, cosine, tangent), and sine, cosine theorems, and geometrical figures;
3. Treatment of numbers: rules of enumeration, sequences of natural numbers, permutations and combinations;
4. Probability: basic laws of probability, independent trial and probability, expectation.

Mathematics II: Objectives of Mathematics II are as the course following "Mathematics I", to help students understand exponential and trigonometric functions, geometrical figures and equations, and variations of values of functions, and to encourage them to master basic knowledge and skills, and to develop their abilities to think and cope mathematically in dealing with various phenomena. The content of "Mathematics II" is;

1. Various functions: exponential functions, logarithmic functions;
2. Geometric figures and equations: coordinates of points, equations of straight lines and circles;
3. Variation of values of functions: differential coefficients and derivatives, and their applications; the idea of integration.

Mathematics III: Objectives of Mathematics III are; to help students deepen their understanding of functions and limits, differential and integral calculus, and to encourage them to master knowledge and skills, and to develop their abilities to think and cope mathematically in dealing with various phenomena. The content of "Mathematics III" is;

1. Functions and limits: rational and irrational functions, composite and inverse functions, limits of sequences and of values of functions, sums of infinite geometrical series;
2. Differential calculus: differentiation and composite functions, applications of derivatives (tangents, increase and decrease of values of function, velocity, acceleration);
3. Integral calculus: indefinite and definite integrals (integrations by substitution and various functions), applications of integrations (area, volume, and distance).

Mathematics A: Objectives of Mathematics A are: as a broader content than "Mathematics I", to help students understand numbers and algebraic expressions, plane geometry, and sequences or computation using computers, to encourage them to master basic knowledge and skills, and to develop their abilities to think and cope mathematically in dealing with various phenomena. The content of "Mathematics A" is;

1. Numbers and algebraic expressions: number systems (integers, rational numbers, real numbers), polynomials, identity, equalities and inequalities;
2. Plane geometry: properties of plane figures, figures determined by conditions, basic theorems, loci, geometric transformation on the plane (congruence and similar transformation);
3. Number sequences: sequences and their summations, recursion formulas and mathematical induction, binomial theorem;
4. Computation and computer: operation of computer, flow charts and programming, computation using the computer.

Mathematics B: Objectives of Mathematics B are; as more advanced content than "Mathematics I" and "Mathematics II", to help students understand vectors, complex numbers and complex number planes, probability distribution, or algorithm using computers, and to encourage students to master basic knowledge and skills, and to develop their abilities to think and cope mathematically in dealing with various phenomena. The content of “Mathematics B” is;

1. Vectors: vectors in a plane, operations on vectors, inner product, vectors in space, coordinates in space;
2. Complex numbers and complex number planes: complex numbers and solutions of equations, simple equations of a higher degree, geometric representation of complex numbers, De Moivre’s theorem;
3. Probability distribution;
4. Algorithms and the computer: function of a computer, programs of various algorithms.

Mathematics C: Objectives of Mathematics C are; through using computers from the viewpoint of applied mathematical science, to help students understand matrix and linear computation, various curves, numerical computation or statistics, and to encourage them to master knowledge and skills, and to develop their abilities to think and cope with mathematically in dealing with various phenomena. The content of “Mathematics C” is;

1. Matrix and linear computation: matrices and their operations, products of matrices, inverse matrices, systems of linear equations (representation by matricies), solution by elimination;
2. Various curves: algebraic expressions and geometrical figures, equations and curves, the ellipse and hyperbola, parametric representation, and polar coordinates;
3. Numerical computation: approximate solutions of equations, numerical integration, mensuration by parts, approximation of integrals of area;
4. Statistics: arrangement of data, representative values and measures of dispersion, correlation, population and samples, normal distribution, concepts of statistical inference.

III. Discussion

This new mathematics curriculum for upper secondary schools was revived by the Ministry of Education in Japan in 1989, and it will be put into place beginning in 1994. I would like to take up some criticism of the reformed mathematics curriculum for Japanese upper secondary schools.

The COM curriculum provides first a core of mathematics for all students, and then provides opportunities for them to enter different streams of mathematics studies. Generally students who do not intend to enter colleges or universities often lose their willingness to learn mathematics when the content is geared mainly to advanced mathematics and teaching methods based upon rigorous proof (Fujita 1987). But the flexible curriculum (COM) is certainly welcome and focuses on a transition from concrete mathematics to conceptual mathematics and on learning the power of mathematical language and symbols from simple to complex (NIER 1990). Therefore the COM curriculum seems appropriately designed for those students.

As noted above, the COM curriculum places emphasis on the use of computers in mathematics education at the upper secondary level. In Mathematics A, a unit is devoted to computation and computers. In Mathematics B, includes the study of algorithms and the computer; course content includes the functions of computers, and programs using various algorithms. In Mathematics C, a chapter is allotted for numerical computation. In this course, the approximate solution of equations, numerical integration, mensuration by parts, approximation of integrals are taught. “Some [students] are taught by using computers. In a positive point of view, using the computer facilitates introduce mathematical concepts and can provide opportunities for exploration and discovery thinking. And those who use computers for mathematics can enrich their mathematical experiences” (Sekiguchi 1989). It seems clear that computers can be used in “doing mathematics”, and their use can provide students with new and interesting ways of learning mathematics. Using computers in the mathematics classroom gives students their first experience with using computers in studying school subjects, helping students to recognize the power of scientific machines.

The computer-related contents of Mathematics A, B, and C form a well-constructed curriculum. However, computer use is not included in Mathematics I, II, or III; this would adversely affect mathematical connections within mathematics topics. Thus it would be desirable to include more emphasis on computer use in Mathematics I, II, and III. It should be mentioned that there are practical problems in using computers in Japanes mathematics classrooms. The proportion of the upper secondary schools that have any sort of computer experience is 89% (March 1988); the number of computers and of teachers who can operate them in individual schools is very limited (Sekiguchi 1989). It is important that the new reformed mathematics curriculum for upper secondary school has no special plan to address these inadequate facilities an aspect of the educational environments that is in great need of improvement. It is also necessary to develop effective teaching methods to make optimal use of computers in the classroom. Although there are many good suggestions for using computers in the mathematics classroom, there is no real blueprint for in-service training for mathematics teachers who use computers to teach their students. The role of teachers’ use of computers is not yet clearly delineated. This is significant obstacle in implementing the new mathematics curriculum.

About 30% of upper secondary school students will enter colleges and universities, and the university entrance examinations have tremendous influence on upper secondary school mathematics teaching in Japan.

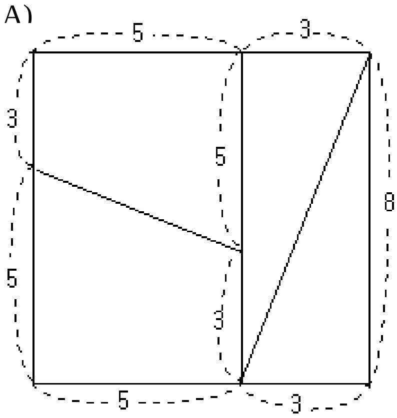
To comment further on the content of the new curriculum, Mathematics I, does not include dependent and independent events for probability. But, as we know, teachers can easily instruct students using examples involving real situations with dependent and independent events. And since "Mathematics I" is required for all students, teachers should consider treating the level and scope of the content flexibly in accord with their students' actual proficiency level when devising their teaching methods. However, teachers have no flexibility in mathematics contents and are restricted in their teaching methods by the centralized system and the college entrance examination system. "Mathematics II", is largely limited to the idea of integration of finding areas in relation to the graphs of functions, but could be expanded to simple real life problems.

There is a large gap between this suggestion and the objectives of Mathematics III. The suggestion would benefit lower achievement students but it is inadequate for those at higher levels. The border between levels should not be restricted, but left to the discretion and expertise of mathematics teachers. Ample application of derivation and integration is essential to the requirements of the information age.

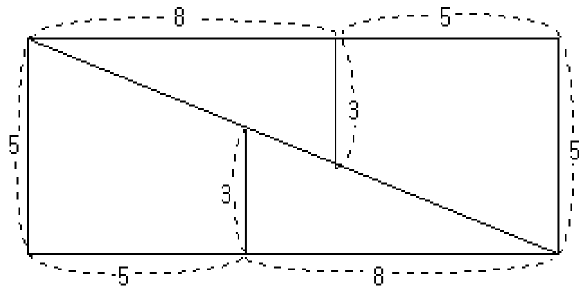
One interesting feature of the new curriculum is the introduction of proof. The new curriculum naturally leads students to proof situations that stimulates students' interest, and forces them to explain their thinking about problems using mathematical expression.

For example, investigate the questions.

A)



B)



Area of A) $8 \times 8 = 64$

Area of B) is $13 \times 5 = 65$

Why the area is different ($64 \neq 65$) (?)

1) Is there something strange? Is this magic?

2) Can you explain what you think about the situation?
3) Discuss your logic in your colleagues.
4) Can you explain your thinking in mathematical language?

When we first face proof questions, in our lives, we are embarrassed or intimidated by such questions. However, students who learn mathematics in the new mathematics curriculum can subconsciously deal with proof questions, and thus enjoy learning difficult topics.

Various textbooks for upper secondary school mathematics have been approved by the ministry, but most often do not use words to explain mathematical concepts, nor do adequately use real life situations to they introduce new topics.

Overall, however, it can be said that, the above mentioned criticism aside Japan's new upper secondary mathematics curriculum is well designed. Of particular merit are its guidelines and recommendations for computer use in the math classroom.

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