Hand Held Calculators in Mathematics Education of Present State in Japan

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1. Introduction

School mathematics curriculum in Japan at primary and secondary school levels is legally requested to be in accordance with the Course of Study prepared by the Ministry of Education, Science and Culture. Current courses of study were put into effect from 1980 (Elementary), 1981 (Lower secondary) and 1982 (Upper secondary). One of the reasons which led the revision at that time was the criticism against the Modern Math Movement. There were also several severe social situations as pointed out by Prof. Kawaguchi, the former President of Japan Society of Mathematical Education. They are, increasing ratio of students to proceed to the upper schools, antipathy to course differentiation and bias to academic course, and competitive entrance examination. (Kawaguchi, 1980). These situations have deep roots in Japanese society and still remain unchanged.

Currently, revision works of the courses of study are being undertaking so that the curriculum guidelines will be able to respond to social needs for 21st century. New ones will be put into effect from 1992 (Elemetary), 1993 (Lower secondary) and 1994 (Upper secondary).

On the other hand, during these years hand held calculators are rapidly spreading over our society. In 1986, for domestic use, 20 million calculators were produced and 10 million ones were imported from other countries (Asahi Shinbun, 1987). Furthermore, cost of the calculator with 4 operations and memory is lowering. It is possible to buy it by 1,000 yen (US $6 or so in 1987).

In everyday life, hand held calculators are becoming familiar, however, Soroban (Japanese abacus), traditional instrument for computation in Japan, unexpectedly remains as before.

About 8 years ago, the International Association for the Evaluation of Educational Achievement (IEA) conducted a survey on calculators and mathematics. The art of state of calculator use in schools of 16 countries were compared and the report was published in 1979 (Suydam, 1979).

In this report, Prof. Shimada, the Japanese reporter, summarized the Japanese situations by a survey on educational journals as follows:

> "For the lower secondary school level, no article or presentation [on the use of calculators] is found in these literatures."

He also distinguished the two teachers' attitude to application of mathematics as in the following and pointed out teachers' "theory-oriented" attitude and entrance examination as major obstacles for the use of calculators.

> 'Among mathematics teachers of the secondary schools, one may find two different attitudes to

mathematics teaching in relation to applications or the function of real situations. The one, which may be called "practice-oriented", is to emphasize a practical side of mathematics and to make the effort to include a certain aspect of model-making into their teaching as much as possible. Teachers of this attitude would welcome use of calculators in mathematics class as an indispensable aid. The other, which may be called "theory-oriented", is to emphasize basic understanding of mathematical concepts and to regard applications or real situations as only examples for illustrating those concepts concretely. In this attitude, numerical complexity in exercises is kept minimum, even when a real-life problem is used as an exercise, so that students might be able to concentrate on mathematical aspects of problems without being bothered by the numerical complexity involved.'

Here in this paper, I will describe present situation in our country on the use of calculators as a continuation of Shimada's report, i. e. since 1980.

2. Present Provision

Government policy on the use of calculators has not been changed as a whole during these 7 years. In the current courses of study, the use of calculators is not refered to as a teaching content, but only refered to in the general remarks entitled "Preparation of the teaching programme and points for special consideration in teaching through all six [three] grades". Basically the treatment is almost the same in the previous courses of study with a slight modification in elementary and lower secondary school levels. In elementary level, the starting grade for the use of calculators was changed from fourth grade to fifth grade. In lower secondary level, appropriate situations were specifically clarified as the mensuration and statistics. In upper secondary level, the remark is the same as the previous one. Verbatim speaking,

[Elementary level] :

In relation to the teaching of the skills of computation, teacher may introduce, if necessary, the use of abacus or calculator in grade 5 and above, but in this case, it is necessary not to disturb the development of such abilities as estimation.

[Lower secondary level] :

In teaching numerical computation of the mensuration and statistics, etc., the abacus, slide rule, or calculator may well be used, if necessary, to increase the effect of learning.

[Upper secondary level] :

Wherever possible pupils should be encouraged to use computer or other mechanical aids to computation.

In accordance with preparation of the course of study, financial support for school accomodation and equipment is provided by the law for promoting science and mathematics education. Central government and local government must subsidize half and half for the cost at school's request. This law was also revised together with the revision of the courses of study. The revised standard for calculator provided by the law and previous standard in parentheses is as follows :

School and Type of calculator	Quantity per Middle size school	Cost per Unit
Elementary school		
Calculator with 4 operations	45 (6	¥3,000 ¥10,000)
Lower secondary school		
Calculator with memory and square root	45 (10	¥10,000 ¥35,000)
Upper secondary school		
Computer : CPU	1	¥2,000,000
; or instead of it, 10 programmable calculators	(Programmable calculator with printer 7	¥320,000 or ¥235,000)
Computer : Peripheral equipments	1	¥2,600,000
; or instead of them, 13 programmable calculators	(Computer or Calculator with more functions 1	¥1,300,000)

(Remark) Midlle size school means:
Elementary school which has 6 classes to 23 classes.
Lower secondary school which has 6 classes to 17 classes.
Upper secondary school which has 301 students to 1,200 students.

In comparison with the previous provision, quantity per one school is increased to 45 (quorum of one class pupils) at elementaly and lower secondary school levels, and calculators are replaced by computers at upper secondary school level.

3. Present State of Affairs concerning Use of Calculators

Here I will illustrate the results of four surveys conducted after 1980 with a view to clarifying how calculators are used in Japanese mathematics education and what attitudes peoples have toward calculators. The four surveys are:

(a) National Institute for Educational Research (NIER) (Ed.) IEA Second Mathematics Study.
Conducted in 1980-1981. 212 schools and 8,091 students at lower secondary school level, and 192 schools and 7,954 students at upper secondary school level were randomly selected in Japan.

(b) Katagiri (Ed.) Survey on the Use of Calculators.
Conducted in 1982. 1,318 parents, 233 elementary school teachers and 23 university professors were selected in Japen.

(c) Sawada (Ed.) Fundamental Survey on Research about Mathematics Education.
Conducted in 1984. 64 university professors were selected in Japan.

(d) NIER Mathematics Education Section (Ed.); Whitman (Ed.) Survey on Mathematics Instruction of Junior High Schools.
Conducted in 1985. 67 lower secondary school teachers were randomly selected in Tokyo.

(1) Use of calculators

Tables 1 and 2 show the subjects in which the use of calculators is encouraged. In 1981, 85% of lower secondary schools and 80% of upper secondary schools in Japan did not use calculators in any subject. In 1985, 75% of lower secondary schools in Tokyo did not use calculators. During these years, calculators have been used in about 15% (1981, 13%; 1985, 16%) of lower secondary

mathematics classes.

Table 3 and 4 show the school's policies on calculators. Calculators with 4 operations have been frequently used in 1% or 2% (1981, 1% ; 1985, 2%) of lower secondary schools. About 10% of lower secondary schools have not provided calculators and 25% or 30% of lower secondary schools have forbidden the use of calculators.

In spite of official encouragement, namely, government policy as mentioned above, teacher's classroom practice in using calculators is not so active against expectation.

Table 1 Subjects in which calculators were encouraged (Source : (a))

	None	Math only	Science only	Math Science	Appropriate Subiect	No Response
Lower S.	84.9%	10.4	0.5	2.8	0.9	0.5
Upper S.	80.2	5.7	5.7	3.1	2.1	3.1

Lower Secondary Schools : 212 schools, Feb. 1981.
Upper Secondary Schools : 192 schools, Nov. 1980.

Table 2 Subjects in which calculators were encouraged (Source : (d))

	None	Math only	Science only	Math Science	Appropriate Subject	No Response
Lower S.	74.6%	11.9	3.0	4.5	3.0	3.0

Lower Secondary School Teachers in Tokyo : 67 teachers, July 1985.

Table 3 Policies on calculators (Source : (a))

	No Policy	Forbidden	May use but not provided	Provided but used rarely	Provided and used frequently	Not avail -able	No R.
L. 4F. C	23.1%	23.6	12.7	33.0	1.4	6.1	0.0
L. Pr. C	23.1	23.1	22.6	14.6	0.5	14.6	1.4
U. 4F. C	35.9	24.0	16.7	15.1	0.5	5.2	2.6
U. Pr. C	34.9	12.0	8.3	34.4	3.6	4.2	2.5

L : Lower secondary schools, U : Upper secondary schools
4F. C : 4 Functions Calculator, Pr. C : Programmable Calculator

Table 4 Policies on calculators (Source : (d))

	No Policy	Forbidden	May use but not provided	Provided but used rarely	Provided and used frequently	Not avail -able	No R.
L : 4F. C	35.8%	29.9	7.5	13.4	1.5	10.4	1.5
L : Pr. C	32.8	23.9	16.4	7.5	1.5	14.9	3.0

L: Lower Secondary School Teachers,
4F, C : 4 Functions Calculator, Pr. C : Programmable Calculator

(2) Attitudes toward the use of calculators

Table 5 shows views of parents, elementary school teachers and university professors regarding the use of calculators by elementary school children. Even in the case of using them from higher grades, views are different among three types. While 17% of parents agree with it, 50% of teachers and 83% of university professors agree with it.

Table 6 shows the views of university professors (mathematics or mathematics education)

Table 5 Views on children use of calculators (Source : (b))

		Agree	Disagree	Not Decided	No Response
Parent	: For Grades 1 - 2	1.7%	91.5	4.9	1.9
	: For Grades 3 - 4	5.0	84.4	8.3	2.2
	: For Grades 5 - 6	16.9	65.9	15.3	2.0
	: For Other Sub.	22.5	43.2	32.0	2.3
Teacher	: For Grades 1 - 2	3.0	88.0	9.0	0.0
	: For Grades 3 - 4	9.0	72.1	14.6	4.3
	: For Grades 5 - 6	49.4	26.6	19.3	4.7
	: For Other Sub.	52.4	14.6	26.6	6.4
Univ. Prof.	: For Grades 1 - 2	4.3	78.3	8.7	8.7
	: For Grades 3 - 4	13.0	69.6	13.0	4.3
	: For Grades 5 - 6	82.6	8.7	8.7	0.0
	: For Other Sub.	69.6	0.0	26.1	4.3

Conducted on March 1982.
1,318 Parents of elementary children, 233 elementary school Teachers.
23 University Professors of Math. Ed.
Grades 1-2, 3-4, 5-6 : Regarding Mathematics.
Other Sub : Subjects other than mathematics.

Table 6 Views on importance of calculators (Source : (c))

	Very Important	Important	Not Decided	Not Important	Not at all Important	No Re.
H. Cal.	46.9%	34.4	14.1	3.1	0.0	1.6
P. Cal.	17.2	40.6	32.8	6.3	1.6	1.6
P. Com.	15.6	42.2	26.6	12.5	1.6	1.6
Comp	7.8	26.6	40.6	17.2	4.7	3.1

University Professors of Mathematics Education or Mathematics : 64 Professors, July 1984.
H. Cal : Hand Held Calculator,
P. Cal : Programmable Calculator,
P. Com : Personal Computer,
Comp : Computer.

Table 7 Attitudes toward hand held calculators (Source : (a))

(Source : (a))

		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	No Re.
A	L	3.4%	10.3	43.7	31.1	10.1	1.5
	U	4.5	22.9	44.8	21.8	3.9	2.2
B	L	12.6	31.3	27.8	18.7	8.2	1.4
	U	24.2	50.6	13.6	7.4	2.1	2.1
C	L	11.2	25.7	47.5	10.7	3.3	1.6
	U	6.2	22.0	45.1	20.3	4.2	2.2
D	L	13.0	28.5	44.6	9.6	3.0	1.4
	U	8.6	30.9	47.7	8.7	1.9	2.1

L : 8,091 Lower secondary students (Grade 7), Feb. 1981.
U : 7,954 Upper secondary students (Grade 12), Nov. 1980.
A : It is less fun to learn mathematical ideas if you use a hand held calculator.
B : If you use a hand held calculator, you do not have to learn to compute.
C : Using a hand held calculator can help you learn many different mathematical topics.
D : Solving word problems is more fun if you use a hand held calculator.

attached to the importance of calculator use in adult life. Here 80% of professors agree with the importance of the use of hand held calculators.

Table 7 shows student's attitudes toward hand held calculators. For example, 14% of lower secondary school students and 25% of upper secondary school students agree with the item "Using a hand held calculator can help you learn many different mathematical topics". But 37% of the former and 28% of the latter disagree with the item. Lower secondary school students are more negative than upper secondary school students in all four items in Table 7.

Reason for this phenomenon is not sure, it may be due to the fact that most of the exercises in the lower secondary school textbooks seem not to require a heavy numerical computation. Therefore there is little chance to appreciate the calculator.

4. Studies on the Use of Calculators in the Classroom

(1) Practices and studies by school teachers

Journals of Japan Society of Mathematical Education (JSME) issued during 1980-1986, published monthly, contain two articles regarding the use of calculators : one on lower and the other on upper secondary. In the annual meetings of JSME during 1980-1986, number of presentations regarding the use of calculators is four in elementary, one in lower secondary and five in upper secondary school level. Considering from large number of presentations (in the total during these years, about 1,200 in elementary, about 590 in lower secondary and about 670 in upper secondary), I conclude that this fact indicates teacher's interest in the use of calculators is much less than other themes.

(2) Studies by university professors

Most mathematicians and mathematics educators have not presented any thought on the use of calculators. However, some are expressing concretely and actively their opinions on the use of calculators. For example, Prof. Hitotsumatsu (Kyoto Univ., mathematician), Prof. Katagiri (Yokohama National Univ., math educator) and Prof. Shimada(Science Univ. of Tokyo, math educator). Their major themes of study on calculator use are as follows : Prof. Hitotsumatsu (1980, 1981, 1986) has presented many mathematical topics for the use of calculators at secondary school level ; Prof. Katagiri (1983, 1984) has surveyed and experimented on the use of calculators in elementary school level and presented many mathematical topics for elementary school level ; Prof. Shimada (1980, 1981, 1985) has presented several ideas regarding the use of calculators in mathematics curriculum over three school levels.

(3) Feasible treatments in the current courses of study

Articles and books mentioned in 4 (1) and (2), and articles in other professional journals (in the total, 16 articles at elementary level, 6 articles at lower secondary level and 9 articles at upper secondary level) are used to identify major mathematics topics which are in the current courses of study and can be learned by the use of hand held calculators. They are by grades as follows :

[Elementary school level]

Grade 5. Areas, Volumes, Estimation, Average, Ratio, Pi, Regular polygons, Percentage, Sector diagram, Band diagram.

Grade 6. Probability, Scale drawings, Direct proportion, Inverse proportion, Statistics, Mutual relation between decimals and fractions.

[Lower secondary school level]

Grade 7. Divisors, Prime numbers, Factorization into prime factors.

Grade 8. Statistics.

Grade 9. Square root, Recurring parts of rational numbers, Graph of quadratic function.

[Upper secondary school level]

Grade 10. Domain of inequalities, Graph of quadratic function, Inverse function, Sine theorem and cosine theorem.

Grade 11. Probability, Statistics, Differentiation, Limit of Sequence, Tables and graphs of exponential, logarithmic, trigonometric functions.

Other topics such as discovering number patterns are found in each school level.

5. Suggestions for Mathematics Curriculum

Let me introduce the current opinions on the use of calculators in mathematics curriculum refering to the papers by Shimada, Katagiri et al. (1981), Shimada (1985) and Shimada, Hitotsumatsu, Katagiri, Uetake, Yoshimura et al. (1985) etc...

(1) Reasons why hand held calculators are not used

Teacher's attitudes, curriculum characteristics and entrance examination seem to be raised as main elements to hamper the use of calculators. It is pointed out that many teachers are "theory-oriented" and have the fear for making lose computational skills and the fear for new change. On the curriculum, it is pointed out that the courses of study and textbooks are developed on the premise of paper-pencil calculation, theory-oriented and avoiding complex numerical values. These trends are strong at lower secondary school level where emphasis is placed on mastering algebraic manipulation and its underlying principles. On the entrance examination, it is pointed out that hand held calculators is traditionally not allowed to use.

(2) Merits of using hand held calculators

There are several merits for the use of calculators and three typical merits are given here. First, we will be able to treat the principles and conceptions through realistic approach. Secondly, it will be possible to have understand more completely with a lot of numerical values. Thirdly, especially at elementary school level, learning on computation and learning on which operation should be applied will be separated. Shimada (1985) characterized the second one as a magnifier or a microscope, namely, a tool for discovery, providing rich data which cannot be obtained by naked eyes only, and the third one as glasses for short sight, namely, an aid for computation, covering weak points in paper-pencil computational skills.

(3) Curriculum effects by more frequent use of calculators

Mathematics education could not escape from the use of calculators and then some changes may happen when calculators are used more frequently.

1) Some topics whose weight may be reduced

Mastering an algorithm by paper-pencil at elementary level and mastering algebraic formulae to be used for paper-pencil computation (e.g. solving a linear equation with fractional coefficient, calculating standard deviation) at secondary level.

2) Some topics which may need re-examination

Role of paper-pencil calculation, grade placement of number concepts (combination of the

number scope and four operations) at elementary level and meaning of solving and solution, and grade placement of the idea of limit at secondary level.

3) Some topics which may be newly introduced

Constructing mathematics theory by using raw data or realistic values, finding or conjecturing rules through numerical experiments and finding numerical values by recurring calculation at each level.

4) Some topics which may be given more emphasis

Mastering the use of round numbers, estimation and approximation, especially in relation with other subjects such as science and social study at each level.

6. Concluding Remarks

Hand held calculators, as mentioned above, seem to me not to occupy the due place in mathematics education in Japan. This trend is predominant, especially, in lower secondary level. Furthermore, to my regret, there is only a few research on the use of calculators in mathematics education.

However, the importance of calculators is recognized in our math educators' community. For example, Japan Society of Mathematical Education made a proposal for improving mathematics curriculum to the Ministry on July 1986. In the proposal, it says : In order to respond the needs of information society, the use of computers and calculators should be more promoted in problem solving learning, etc... Moreover, "Specification of hand held calculators at each level" (Fujita et al., 1986) has been advocated in the annual meeting of JSME in 1986.

Finally, I will discuss implication of introducing the use of hand held calculators into mathematics curriculum as a new topic. There are several criteria to judge whether a proposed new topic is worthwhile to introduce into school mathematics curriculum. For example, importance in mathematics, needs of society and appropriateness for child development are some of them. Difficulty of learning it by oneself in society is another one. That is to say, if the topic can be learned by oneself after or outside the school, it need not to be introduced into school curriculum as a new topic. If hand held calculator is considered only as an aid for computation, eye-glass function, it need not to be introduced into school in haste. Because it will become much easier than today to master hand held calculator by oneself according to technical progress.

Mathematical activity in which children construct their own mathematics from their reality is recognized as one of the most important aspect of mathematics teaching. Here we could find a right place for hand held calculator. Because it seems that it has a great possibility of a means for promoting such an activity, through its magnifier or microscope function. If we could use hand held calculators, some new activity could be realized in mathematics classrooms.

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REFERENCE (* means that it is written in Japanese.)

Asahi Shinbun. 40% of hand held calculators imports. 14 Jan. 1987. (*)

Fujita, H. et al. Recommendation of standardization of hand held calculators for mathematics education. 1986. Journal of JSME. Vol. 68. Supplementary Issue. JSME. p. 418. (*)

Hitotsumatsu, S. Bring hand held calculators into math classroom ! I. 1980. 189p., II. 1981. 190p., III. 1986. 171p. Kaimeisha. (*)

Katagiri, S. (Ed.) Hand held calculators in mathematics education of elementary school. 1983. Yokohama National University. 55p. (*)

Katagiri, S. & Kimura, H. The Implementation of the Calculator in Improving the Elementary School Mathematics Curriculum. 1984. Proceedings of ICMI-JSME Regional Conference on Mathematics Education. JSME. pp. 149-152.

Kawaguchi, T. Secondary School Mathematics in Japan. 1980. Studies in Mathematics Education. Vol. 1. UNESCO. pp. 39-59.

National Institute for Educational Research (Ed.) Mathematics achievement and associated factors of secondary school students. 1982. NIER. 178p. (*)

NIER Mathematics Education Section (Ed.) Report of survey on mathematics instruction of junior high school. 1986. NIER. 100p. (*)

Sawada, T. (Ed.) Report of fundamental survey on research about mathematics education. 1985. NIER. 152p. (*)

Shimada, S. Calculators in Schools in Japan. 1979. Working Paper on HAND HELD CALCULATORS IN SCHOOLS. IEA International Working Group on Calculators. pp. 34-38.

Shimada, S. International survey of the use of calculators in school mathematics. 1980. Journal of JSME. Vol. 62. No. 9. JSME. pp. 27-33. (*)

Shimada, S. Hand held calculators in mathematics education. 1985. Issues on mathematics education —Hand held calculators & Geometry education. Ace shuppan. pp. 9-23. (*)

Shimada, S., Katagiri, S. et al. Mathematics education in elementary school and hand held calculators. 1981. Elementary Mathematics Teaching Today. No. 125. Society of Elementary Mathematics Education. pp. 12-27. (*)

Shimada, S., Hitotsumatsu, S., Katagiri, S., Uetake, T., Yoshimura, S. et al. On education using hand held calculators. 1985. Issues on mathematics education—Hand held calculators & Geometry education. Ace shuppan. pp. 51-83. (*)

Suydam, N. M. (Ed.) Working Paper on HAND HELD CALCULATORS IN SCHOOLS. 1979. IEA International Working Group on Calculators. The Ohio State University. 90p.

Whitman, N. (Ed.) Mathematics Instruction in Tokyo and Hawaii's Junior High Schools. 1986. University of Hawaii. 51p.

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