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The desk calculator has been promoted as invaluable to the teaching of mathematics, though this claim has not been supported by controlled experimental studies. Using empirical methods, this study was designed to test calculators with two groups of ninth grade students and one group of fifth grade students in three differing instructional settings. Experimental and control classes were designated for each group, and, in addition, one ninth grade group contained a class to control for the "Hawthorne effect." An attempt was also made to control for differences in teacher performance. The findings were equivocal concerning the effect of calculators on the students' performance and on their self-confidence and attitude toward mathematics. Teacher enthusiasm for use of the calculators bore no relation to the machines' effect on student performance. Rather, this enthusiasm appeared to be a function of the calculators' effect on student-teacher interaction and their potential as toys to provide classroom diversion. The lower the average IQ level of the group, the higher was teacher enthusiasm. At worst, the machines took up space and cramped daily operations. At best, they gave a feeling of increased productivity to students not previously capable of it, thereby easing classroom behavior problems. (GO/MT)

DESK CALCULATORS IN THE MATHEMATICS CLASSROOM.

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DESK CALCULATORS IN THE MATHEMATICS CLASSROOM*

Introduction

The classroom is becoming more and more mechanized every day. It seems that today's teacher cannot be considered progressive unless he has on hand overhead projectors, film strips, tape recorders, etc., and access to language labs, educational television and teaching machines. But as with any wave of new innovations, it takes time to sort out technologies which are merely technical from those that make a definite contribution to the learning process. Students and teachers both are quick to develop an interest in something mechanical. It is the responsibility of the educator to distinguish between interest generated by a 'gimmick' in and of itself and interest in the process or the subject matter for which that 'gimmick' is meant to be a vehicle. It was the purpose of this study to separate the mystique surrounding a technology from its functional value as an aid to learning.

The Role of the Manufacturers

This study is concerned with desk calculators, electric machines that add, subtract, multiply and divide. Recently such machines have been credited with making for substantial improvements in the learning of mathematics, especially with regard to slow learning students. Manufacturers have been making a concerted effort to demonstrate to teachers and school officials the benefits of these machines and in fact, part of the impetus for this study came from one of these manufacturers.[1] This company had developed a programme which outlined how its machines could be integrated into the classroom and as part of its sales promotion, the company has put together a loose-leaf binder filled with testimonials to the effectiveness of the machine. These are in the form of either newspaper articles or letters from school officials, extolling the benefits that the machines provide, especially with students who have had previous difficulties with mathematics. The newspaper articles invariably stressed the originality of the innovation with such descriptions as: "a new method of teaching arithmetic that is as modern as the computer programme that inspired it" (The Colorado Springs Gazette-Telegraph), or "an entirely new idea in the teaching of math" (The Hobart Oklahoma Democrat-Chief) and the "trail-blazing use of electric calculators as teaching tools" (The Des Moines Register). The letters, which included a number from the Metropolitan Toronto area, stressed the motivational benefits of the machines noted by teachers. (The final reprint in the loose-leaf binder had nothing to do with desk calculators, but instead was a portion of an article from Life Magazine in which a college president discussed the importance of encouraging his staff to be creative and original.

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*CCRE is pleased to bring you this paper. The ideas expressed are those of the authors.

[1]Machines for the study were provided free of charge by two manufacturing companies.

The implicit message was that the good teacher is a progressive innovator, i.e. one who uses desk calculators in his classroom)

In every case the evaluations found in the letters and articles in the "sales promotion kit" were the opinions of the teachers involved. There were no examples given of experimental studies involving treatment and non-treatment groups in a controlled situation. Furthermore, correspondence with educators suggested by the company as having done work in this field, did not result in any information of this latter type.

Earlier Experiments

Claims as to the novelty of this type of innovation are ill founded. A review of issues of The Mathematics Teacher, an official journal of the American National Council of Teachers of Mathematics, dating back to 1926, revealed four articles on desk calculators, the earliest being in 1937. Issues before 1926 were unavailable but the Index reported two other articles previous to that date on the same subject. Of the four articles available, only one, "The Use of Calculating Machines in Teaching Arithmetic"[2], had an experimental bent. The author reported his impressions after giving his class access to calculators, noting that in the past, students "had never evinced any enthusiasm for this...course". Although his experiment made no allowance for a control group nor for anything but subjective measures of attitude and motivation, he reported that the machines were a strong motivating force with no sacrifice of analytic skills. The author also cited a 1934 Ph.D. thesis[3] on the topic which employed a control group and found that that group fared slightly better in arithmetical ability although the teachers involved noticed an improved attitude for the Experimental group.

Other articles in other journals were of a similar type. All enthusiastically recommended the use of desk calculators and noted improved motivation on the part of students. None based the recommendation on empirical grounds. One described the design of an experimental study in 1960[4] and noted improved student motivation at the outset, but a promise to report back with the final findings was not kept, or at least there was no record of it in the Educational Index. The literature then, has been consistently enthusiastic about the use of desk calculators in the teaching of mathematics but conspicuously non-empirical as well.

The Hypotheses

The current revival of interest in desk calculators gives rise to three basic questions: (1) What conditions have facilitated the reappearance of the innovation at this particular time? (2) Are there measurable changes that could be attributed to the use of the machines that relate to the students' ability to do mathematics and their self-confidence and attitude towards the subject? and (3) Why do teachers become enthusiastic about the use of desk calculators?

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[2] W.S. Schlauch, The Mathematics Teacher, January, 1940, pp. 35-38.

[3] F.G. Marsh, "An Experimental Study of Facilitation and Interference Effects of Calculating Machines Upon Arithmetical Skills", a Ph.D. thesis submitted to the University of California, 1934.

[4] Lois L. Beck, "A Report on the Use of Calculators", The Arithmetic Teacher, February, 1960.

It was not feasible to react fully to the first question within the framework of this study; however, it can be suggested that a number of factors contributed to this situation. To begin with, there is a greater emphasis upon and monies available for education today than ever has been the case in the past. Consequently, this has resulted in an increased use of technologies as teaching tools and while not all technical innovations tried, made positive contributions to the learning process, desk calculators, buttressed by the performance claims of the manufacturers, have looked especially promising. Finally, the middle 'sixties have been years of economic boom. A review of the literature showed that interest in this innovation was highest at similar times in the past, the early 1920's, the late 'thirties, and the early and middle years of the 'fifties.

Two hypotheses were derived in an attempt to answer the last two questions. The first hypothesized that the introduction of desk calculators into a mathematics classroom would bring about a significant change in (a) the ability of the students to perform basic mathematical operations and to solve mathematics problems, and in (b) their self-confidence and their attitude towards mathematics. The second hypothesized that teacher enthusiasm for the machines would be a function of their effect upon student-teacher interaction in the classroom rather than on student performance. Data relating to the first hypothesis were collected through the use of written tests and questionnaires, while data relating to the second hypothesis were obtained from interviews with teachers and classroom observation.

Design of the Study

The study was conducted with three distinct types of students in three different settings: Grade 9 students in a technical secondary school (average IQ 90), Grade 9 students in a vocational school (average IQ, 80), and Grade 5 students from the regular elementary school programme (average IQ, 115). With the first group, Experimental, Hawthorne[5] and Control classes were designated; in the other two groups, there were Experimental and Control classes only. For the Experimental students the machines were integrated into the curriculum; Hawthorne students could use the machines to check work at the end of the class period or after school; Control students did not have access to the machines at all. It was realized that differential teacher performance could influence the results of the study. In an attempt to reduce this factor, teachers involved in the experiment taught classes of each type where possible. The treatment period ran for from four to five months, depending on the group.

Pre- and post-tests given to the students employed the same set of instruments, although Grade 5 students completed similar but slightly modified forms from those completed by the Grade 9 students. The mathematics tests were made up of questions modelled after those in their texts with care being taken to ensure that the instrument was neither too easy nor too difficult and that pre-test scores would allow for improvement over the treatment period.

The questionnaire incorporated sections relating to self-confidence and attitude towards mathematics. This instrument was devised specifically for this study since other scales used to measure similar characteristics were found to be not suitable. All instruments were tested at length for their

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[5] Hawthorne groups theoretically experience the heightened excitement of the innovation without the specific learning influence with which the study is more directly concerned.

suitability with similar students at different schools and the results obtained were subjected to a factor analysis, adjusted, retested and reanalyzed until there was assurance that they did in fact measure what they were designed to measure.

A structured interview was conducted with each teacher of an Experimental class at the conclusion of the treatment period. Questions focussed on the effects of the calculators on student performance and attitudes as perceived by the teachers, on their effect on classroom discipline and on the teachers' recommendations for further use of the machines. In all, ten teachers were interviewed, four from the technical secondary school, two from the vocational school, and four from the elementary schools. The elementary school teachers taught only Experimental classes (four other elementary school teachers taught the Control classes), but all other teachers taught both treatment and non-treatment groups. In assigning classes to treatment or non-treatment groups, care was taken to see that they were matched on the basis of previous academic performance, IQ, and socio-economic status. In addition, Experimental and Control teachers in the elementary schools were matched on the basis of informal board ratings and teaching experience.

During the treatment period teachers followed their normal curriculum, integrating the machines into the programme of the Experimental group. Meetings were held by the teachers to coordinate work covered and teaching techniques so that a standard programme, with the exception of the independent variable would be received by all students. The analysis of the data from the mathematics tests and the questionnaires employed the t-test technique to determine the significance of mean differences between groups from pre- to post-tests.

The Findings

The results of the tests were equivocal at best. In all three groups there was no significant difference shown in improvement in mathematics skills between Experimental, Control and Hawthorne groups. However, the self-confidence and attitude to mathematics factors showed considerable variance from group to group. At the technical secondary school there was no significant difference among the Experimental, Hawthorne and Control groups with regard to self-confidence. In attitude towards mathematics however, the Experimental group showed greater increases than the Hawthorne and Control groups (significant at the .05 and .01 levels of confidence respectively). There was no significant difference between the Hawthorne and Control groups.

At the vocational school, the opposite results were noted; the Control group showed greater increases in both self-confidence and in attitude to mathematics than did the Experimental group. Differences in both cases were significant at the .05 level of confidence.

Findings for the Grade 5 students were more in line with those of the technical secondary school students. Differences from pre- test post-tests favoured the Experimental group for both self-confidence and attitude to mathematics and in both cases were significant at the .05 level of confidence.

It would appear then, that the evaluations made in the literature and presented in the sales promotion kit, were not substantiated. Desk calculators were claimed to be especially effective with slow learning students but the least academically able group in this study, the vocational students, showed greater motivational increases among the Control group students than among the

Experimental students, while the technical secondary school students showed no significant difference among groups in the measure of self-confidence. Only the Grade 5 students showed significant increases in favour of the Experimental group in both self-confidence and attitude towards mathematics. In addition, the desk calculators appeared to have no significant effect upon the ability to solve mathematical problems for any of the three groups. Thus the first hypothesis, that the introduction of desk calculators into a mathematics classroom would bring about a significant change in (a) the ability of the students to perform basic mathematical operations and to solve mathematics problems and in (b) their self-confidence and their attitude towards mathematics, must be rejected for part (a) while judgment is reserved for part (b).

Teacher enthusiasm bore little relation to the findings of the objective tests. If recommendations for purchase can be used as an index of enthusiasm, then vocational school teachers were the most enthusiastic and elementary school teachers the least. Vocational school teachers recommendedthat complete classroom sets of machines be bought for every teacher in the math programme. One technical secondary school teacher felt the same, but the other three recommended that a single classroom set, that could be used in rotation, be purchased. The elementary school teachers were more hesitant, one giving an outright 'no', two saying that such a purchase would be very low priority, and one recommending the purchase of only two or three machines to be kept at the back of the room. Thus the teachers of students who seemed to receive the most benefit were the least enthusiastic about their use and vice versa, those whose students received the least benefit, the vocational school teachers, were the most enthusiastic.

The teachers were also asked if they thought that the machines affected the students' ability to solve mathematical problems. All four elementary school teachers and one technical secondary school teacher responded 'no'. The other teachers thought that the machines had a positive effect in this area; it will be remembered that there were no significant differences for all types of students in this regard. All teachers surveyed felt that the attitude of their students towards mathematics was improved because of the presence of the desk calculators. Thus only the elementary school teachers made an evaluation of the capabilities of the machines in affecting student performance and behavior that reinforced the findings of the tests.

Discussion

The evaluations of the vocational school teachers, and to a lesser extent the technical secondary school teachers, were not substantiated on the basis of empirical data. The question that arises then, is why do these teachers enthusiastically recommend the use of desk calculators when objective proof of their efficacy is lacking. It could be suggested that the answer lies in the influence of the machine on student-teacher relationships and on its potential as a classroom diversion, that is, a toy.

It is interesting to note that the lower the IQ of the group, the greater the enthusiasm of the teachers for the use of desk calculators. Students in the vocational school and in the technical secondary school have had a history of poor academic performance. It has been said that they also have a shorter attention span and are more difficult to control than are students in the general high school or elementary school stream. They have less interest in academic subjects. (The Grade 5 students scored much higher on the pre-test attitude to mathematics than did students from the other two areas.) The presence of desk calculators helped to ease some of these problems and to restructure the classroom confrontation by giving the students a toy to play with. The toy reduced the drudgery associated with the mathematics class and instead made it fun; the students became more eager to come to class. Moreover the toy was approved in that it could be thought of as contributing directly to the mathematical learning process. Such a contribution was deceptively visible as the students, by manipulating their toy, could obtain the correct answer to more questions than ever was possible before. Both efficiency and productivity increased with the use of the desk calculator. There was no increase in the understanding of the mathematical concepts involved, however; there was no significant difference between treatment and non-treatment groups in their improvement in handling mathematical problems. Neither was there conclusive evidence for these groups that motivational aspects, self-confidence and attitude towards mathematics, were improved. Experimental students at the vocational school fared poorer than the Control group in this area while those at the technical secondary school showed a greater improvement in attitude to mathematics, but did not change with regard to self-confidence.

What did change for these students was their behavior in the classroom. The researchers observed that for the Control group and in the past for the Experimental group, classroom behavior often tended to be disruptive. With the advent of the calculators, the students' energy and interests were vented upon the machines in a teacher-approved manner rather than on each other and the teacher in a way that disrupted the class. The machines provided a diverting interest to supplement low motivation with the result that the classroom atmosphere became calmer and more controllable. For the teachers then, two main results were visible, an increase in productivity and an improvement in classroom behavior.

But what of the good students? Why did their teachers not share in the enthusiasm? The elementary school teachers were aware of the objective benefits of the desk calculators, but their evaluation of the machines was also a function of the influence on the classroom situation. Student motivation was improved by the presence of the machines but it was already high in the Grade 5 classroom. The same can be said of productivity and efficiency. These were not problems for the elementary school teachers as they were for the others. Classroom control was also good and did not require an extra stimulus to retain interest. Thus the benefits provided by the desk calculators were not in areas of pressing need for the elementary school teachers. In addition, there were environmental conditions in the elementary school classrooms, not found in the vocational and technical secondary schools, that made the use of the machines more problematical. Although the size of the rooms were about the same, the classes were much larger in the elementary school, 30-35 students compared with 20-25 in the technical secondary school and 10-15 in the vocational school. Thus more machines had to fit into less available space and often impinged upon display areas and surfaces used for the other subjects. These teachers found that the problems for daily operations brought on by the machines were greater than the perceived motivational benefits for the students.

Our second hypothesis then, that teacher enthusiasm for the machines would be a function of their effect upon student-teacher interaction in the classroom rather than on student performance, seems to hold. Although empirical tests were negative or inconclusive, vocational and technical secondary school teachers were enthusiastic about the use of the machines because they cut down on behavioral problems in the classroom and increased efficiency and productivity in day-to-day work. Elementary school teachers, whose students were already well motivated, efficient and productive, and for whom the machines took up needed space and cramped daily operations, felt that the machines were low priority items, despite noted increases in self-confidence and attitude towards mathematics.

It becomes clear then why desk calculators are recommended for use by slow learning students. They fit into the environment of the classroom and make the period more enjoyable for the students. In addition, they give the appearance of increased productivity and efficiency among students who have not previously been noted for these traits. In general, the classroom confrontation between student and teacher is made more orderly, resulting in an atmosphere of less stress for both parties. These are important functions and in performing these, the machines serve a useful purpose. The functional importance of the innovation, however, lies in its potential as a toy rather than as an aid to learning. As such, it is unlikely that desk calculators will be an educational innovation of any permanence; real toys cost considerably less.

TABLE 1

MATHEMATICS TEST SCORES

		Pre-test Score	Post-test Score	t	Significance Level
Vocational	Experimental (34)	9.8	10.5	0.20	n.s.
	Control (27)	8.8	9.6		
Technical Secondary	Experimental (74)	17.5	20.2	Experimental-Hawthorne 0.21	n.s.
	Hawthorne (45)	17.2	19.8	Experimental-Control 1.74	n.s.
	Control (31)	17.7	19.7	Hawthorne-Control 1.27	n.s.
Elementary	Experimental (120)	17.3	19.6	1.08	n.s.
	Control (110)	17.6	20.3		

TABLE 2

SELF CONFIDENCE

		Pre-test Score	Post-test Score	t	Significance Level
Vocational	Experimental (34)	11.6	11.5	2.28	0.05
	Control (27)	9.4	10.8		
Technical Secondary	Experimental (74)	13.2	11.2	Experimental-Hawthorne 0.22	n.s.
	Hawthorne (45)	13.4	11.3	Experimental-Control 0.11	n.s.
	Control (81)	13.4	11.6	Hawthorne-Control 0.67	n.s.
Elementary	Experimental (120)	20.6	21.2	2.40	0.05
	Control (110)	20.8	20.2		

TABLE 3

ATTITUDE TOWARDS MATHEMATICS

		Pre-test Score	Post-test Score	t	Significance Level
Vocational	Experimental (34)	10.5	10.9	2.04	0.05
	Control (27)	9.6	11.0		
Technical Secondary	Experimental (74)	9.0	9.5	Experimental-Hawthorne 2.11	0.05
	Hawthorne (45)	9.4	9.1	Experimental-Control 4.19	0.01
	Control (81)	9.8	9.0	Hawthorne-Control 1.35	n.s.
Elementary	Experimental (120)	16.0	16.5	2.50	0.05
	Control (110)	16.9	16.4		