CHAPTER XVII

GENERAL SUMMARY AND DISCUSSION

The project described in this book comprises three separate investigations, all of a practical educational nature and carried out in accordance with an experimental design in a concrete school environment for direct application in practical school work. In all three cases I was concerned with the geometry instruction in grade 4. In order to avoid the otherwise difficult problem of keeping the teacher factor constant, the investigations were carried out with the aid of programmed booklets. The teacher's intervention was minimal and when it occurred, it was controlled by me through detailed instructions. The project is an attempt to shed light on a distribution problem in geometry teaching in grade 4. In part I an account is given of an investigation concerning the optimal distribution of the number of lessons containing measurements and calculations in the geometry instruction. In part II I take up the problem of how the course should be distributed for optimal results during the spring term in grade 4. In part III I attempt to shed light on the question of the optimal working time per lesson period for the geometry instruction in grade 4, when this instruction is carried on with the aid of programmed booklets.

Part I is entitled "The Teaching of Geometry in Grade 4—Measurement or Calculation?". The investigational work was carried out in Uppsala county in the school years of 1961–2 and 1962–3 and comprised 36 classes. Part II is entitled "The Optimal Concentration of the Geometry Course in Grade 4". The work was carried out in Uppsala and Gävle in 1965 and comprised 30 classes. Part III is entitled "The Optimal Working Time per Lesson Period for the Geometry Instruction in Grade 4, Using Programmed Booklets". The work was done in Västerås in 1965–6 and comprised 20 classes.

The results of the three investigations will not be reproduced here in detail, as detailed accounts have already been given in the summaries to each part (Chapters VII, XII and XVI). The interested reader should turn to these chapters in the first place, in order to get a more complete picture of the experiments performed. In the following sections I only intend to give an account of the main results and to discuss them to a limited extent.

Part I

The basic geometry instruction in grade 4 can be carried on in many different ways. It can be imagined as lying anywhere at all along a bipolar instructional continuum, in which one pole is distinguished by visual teaching. Thus, the instruction may be quite visual but may also involve a method of learning in which the pupils have to learn to carry out abstract calculations without getting a grounding based on their own experience, as many teachers and research workers consider is necessary. Is there any optimum in this continuum, an optimum based on the pupils' results in achievement tests, comprehension tests, attitude tests and questionnaires? What consequences will one method or the other have in grade 5? In order to illustrate a series of such questions, an experiment was performed in grades 4 and 5 on four groups of pupils (E, K1, K2 and K3), whose geometry curricula in grade 4 were the same, viz. the course laid down in *Läroplan för grundskolan.* On the other hand, the ratios of measurements to calculations were not the same in all the groups.

Group	Measurements	Calculations	Unit conversions
E	13	0	2
K1	8	5	2
K2	6	7	2
K3	3	10	2

In order to reduce the teacher's influence on the results, the instruction was given in the form of prepared booklets, as has already been mentioned. The sample was followed up to grade 5, in which the geometry instruction was given in the same way, i.e. with the aid of booklets. However, in this series the ratio of measurements to calculations was the same for all four groups.

If we place the groups on an equal footing in the initial situation by using analysis of covariance and consider the results of all the tests included, we shall reach the following conclusions:

1. The fact that no calculations occur is of no significant advantage in the teaching of geometry in grade 4.

2. The pupils are well able to cope with the grade-5 geometry course, even though they have not done any calculations before.

3. Doing calculations does not present any special difficulties to pupils in grade 5. This applies irrespective of how the instruction in grade 4 was arranged, as regarded measurements and calculations.

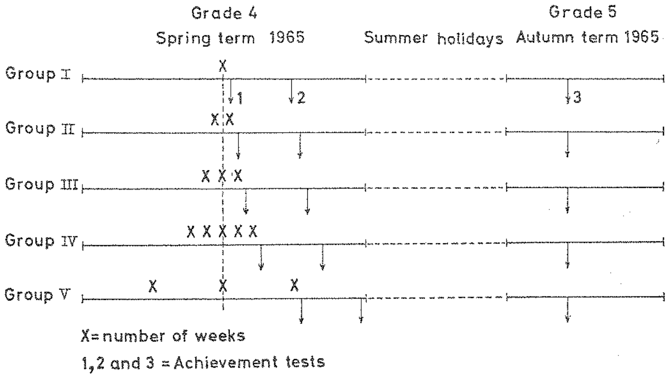
Thus, in grade 4 visual geometry instruction, containing a great many measurements, does not seem to produce any markedly better effect than instruction containing a great many calculations. There is scarcely anything in the way of results, with the possible exception of a repeated but not significantly better retention in the unit-conversion test for the measurement group (E), which argues that an exaggerated use of visual instruction would facilitate learning, improve the knowledge retention and the comprehension and produce a more positive attitude to the subject. Comenius, Rousseau and Pestalozzi inculcated the importance of visual impressions in teaching, partly as a reaction against mediaeval theoretical instruction, and today this teaching principle is, of course, fully accepted and seems to be self-evident. But is it so self-evident that its correctness does not even need to be proved? It almost seems as if this is so. It is true that a number of investigations have been carried out (Thiele, 1938; Miller, 1957) in which research workers have studied the effect of using visual material in teaching. In general the results argue *in favour* of visual instruction but we must also note and may also concur in the statement by Flournoy that "Carefully designed experiments to evaluate the effect of visual arithmetic materials on arithmetic understanding have not been reported" (Flournoy, 1964, p. 70).

As regards the practical application of teaching principles (Koort, 1967), it is interesting to note how an oscillatory motion comes into existence as a consequence of the discussion which arises when the optimum in the continuum of a teaching principle is exceeded (for example, individualizing and frontal teaching, induction and deduction, concentrated and dispersed). During the last 50 years it may be observed from the curricula how rapidly the pendulum has swung over to the concretion pole. At the same time one notes that there is a delaying action or a healthy sceptical attitude towards innovations on the part of the teachers, in this case against an *exaggerated* use of visual material in the sphere of geometry teaching. In all three investigations I have tried to get an idea of the teachers' attitudes to the question of how the measurements and calculations in the geometry instruction in grade 4 should be distributed. In this connection it will be found that in the first two investigations (parts I and II) the teachers consider that *calculations should occupy more time* than measurements. Only in the third investigation do they assign measurements a somewhat greater importance than calculations. Thus, it is a matter of a gradually changing attitude, and perhaps this is a sign that the ideas of the new curriculum are beginning to be accepted by the teachers. *According to this curriculum, measurements are to predominate entirely in grade 4, a prescription which evidently does not agree at all with the teachers' views.* Of course, I neither can nor wish to reject the visual principle in teaching on the results of this investigation, but we should perhaps adopt a wait-and-see attitude towards a tendency which exists today in the direction of an *exaggerated* use of *visual material and aids,* on the whole, in both junior and senior teaching. Thus, it does not seem unreasonable to assume that, at least as regards the geometry instruction in the intermediate stage of the primary school, we could simply take it for granted that the concrete experience is already provided by life itself. The question is surely whether the optimum in the continuum, as regards visual teaching, has not now been exceeded. Visual teaching must not become an aim in itself; as we all know, it is only a means of achieving the aim, which is to understand and employ more and more abstractions.

Part II

In an attempt to shed light on the question of the importance of concentration for achievement, retention and attitude formation in grade-4 pupils, five groups of pupils were given a programmed geometry course under different conditions of concentration. Thus, the content and form of the instruction were constant in all the experimental groups, but the concentration of the learning varied between the groups, as shown in the following survey:

The survey shows, on the one hand, how the instruction for the respective groups was differently distributed, in a symmetrical manner, around the middle of the term and, on the other, that three equivalent achievement tests (P1, P2 and P3) were given to all the groups immediately after the end of the instruction, 33 days later and after the summer holidays, on 16 September. With this arrangement it was possible to shed light on the question of the short- and long-term effects of the different concentration conditions in respect of achievement. In addition, a number of attitude tests were administered in the course of



the experiment. By this means I was able both to record within-group fluctuations and to make between-group comparisons and thus observe the effect of the different experimental conditions on the pupils' attitudes, both in the short and the long run. The attitude tests were given in the initial situation (Att. I and II), after half the geometry course had elapsed (Att. III), after the end of the course (Att. IV), and in P2 (Att. V) and P3 (Att. VI). In order to supplement and diversify the results obtained in the attitude tests, questionnaires were addressed to both the teachers and the pupils. The following main results were obtained:

1. Geometry instruction, using programmed booklets, produces in grade-4 pupils a very noticeable positive attitude to the subject during the period for which the instruction goes on.

2. In respect of attitude the instruction produces significant differences between the sexes, in favour of the boys.

3. The different experimental conditions produce neither significant short- nor long-term effects in the attitude variable, with one exception, viz. after half the geometry course, when it may be observed that the attitudes of the pupils in group I are clearly more positive than those of the pupils in group V.

4. The distribution of the instruction over three weeks produces by far the most positive attitude. Concentrated instruction produces, on the average, a somewhat more positive attitude than dispersed instruction.

5. To a direct question, both teachers and pupils answered that the most suitable concentration of the booklets was one every other day.

6. There are differences between the sexes in the achievement levels in all three tests. The differences, which are not significant but are in favour of the boys the whole time, tend to be greater the longer the time that has elapsed since the actual learning.

7. In spite of the relatively high attitude level, on the average, concentrated instruction produces clearly negative long-term effects in respect of achievement, while dispersed instruction produces particularly good long-term effects. Immediately after the end of the instruction, there are, on the other hand, no differences in the achievement level between groups representing different concentration conditions.

A reasonable explanation of the very positive reception which the pupils gave the programmed course would seem to be the change and the novelty value signified by the new form of instruction. It is more difficult to express an opinion about the reason for the fall in attitude level which already ensues after half the geometry course has elapsed. Can it be due to the pupils simply losing interest very rapidly in such instruction? As is well known, the difficulties involved in carrying out a field investigation with a strictly experimental design are many and great ones. One factor which I did not succeed in keeping under control and therefore do not know what effect it had was the influence of the rest of the mathematical instruction on the knowledge retention and the learning in the groups which worked under dispersed conditions. In these cases the time which elapsed between the geometry lessons was so long that for practical reasons it simply had to be used for other instruction.

The most applicable conclusion from this investigation for practical use in schools would seem to be that in the long run the best effect on the achievement side is obtained *if the instruction is not concentrated* too much. The optimal condition, which I would have recommended with no great hesitation if the achievement level had been higher still in the last achievement test, is the condition represented by group III, i.e. the distribution of the instruction over three weeks. Not only is the group's attitude more positive throughout than those of the other groups but also the achievement level immediately after the end of the instruction is higher. One month later the level is still relatively very high. In the final situation group III still performs better than the groups with concentrated instruction but *significantly worse* than the group whose instruction was most dispersed in time (group V).

I shall not describe here all the different secondary results which were obtained. By way of conclusion, I shall briefly explain my view as to how the results and the experiment should be regarded in relation to previous related research and whether it is possible and reasonable to apply the results generally in a somewhat larger context.

As regards the question of concentration in learning, we may record, by way of summary, that the experiments which have been carried out in this field have in general been considered to be of too theoretical a character, while applied experiments which have actually been carried out in connection with practical school work have in most cases lacked an experimental plan and have therefore been too difficult to draw conclusions from. We may also add that it seems to be only a question of a similarity in terminology and not of an actual relationship between the so-called concentrated learning in the laboratory experiments and the concentration study, as it is carried on by teachers.

The question of the concentration of instruction is a didactic problem with an apparently minimal connection with theory. It certainly seems as if the problem of massed and distributed practice is subsumed under this question and it would therefore be interesting if we could get from this practice some reasonable points of departure that would also serve in the sphere of didactics. If these two problem complexes could be *directly* related to each other or simply regarded as identical, I could also give several theoretical explanations of the results which have emerged from the investigation. I must admit that I was often tempted to do so but for different reasons always refrained. The most important reason was that I simply did not consider that the problem of massed and distributed practice was of direct relevance to the question of concentration in instruction, though there is no doubt a similarity. An enormous number of investigations have been carried out in this sphere, but these experiments have for the most part been of a very theoretical character and have been carried out with the aid of rats and labyrinths, have used paired associations and been concerned with pursuit rotor learning, mirror drawing, etc. Most of them have been of a basic research character. Investigations of a more applied character have been concerned with badminton, basket ball, archery and the like. As far as I can judge, previous investigations have mainly included the practice of skills of various kinds, in which the conditions of massed and distributed practice were compared and in which a certain material, a certain skill or the like was learned as a whole on one and the same occasion. The rat which is to learn the plan of the labyrinth and which runs from start to goal shows all its dexterity in doing so, though it does not do so faultlessly. It is carrying out a trial. Trials may afterwards be carried out under the conditions of massed or distributed practice. This is obviously not the case in the programmed geometry course given in the present investigation. A confusion in linguistic usage is noticeable, as regards massed and distributed practice, to such an extent that people speak of this concept in reference to didactic concentration and even roughly generalize results obtained from laboratory experiments in learning in a single trial to apply to learning in practical school work. In spite of this and of the fact that such an antithesis actually exists, one must admit that a certain similarity in results can also be observed. As is well known, it has generally been found that distributed practice facilitates learning and retention. The present investigation has yielded a similar result. *A likely interpretation would be, in the first place, that an identical pattern or a general latent structure exists for both simple laboratory experiments in massed and distributed practice and more complex and applied skills, such as archery and multi-dimensional educational experiments. In the second place, it seems reasonable to assume that this possible latent factor must be a strong one, since it makes itself felt in both simple trial learning and multi-faceted learning in complex educational situations.*

Part III

The relation between the experiments reported in parts II and III is a macro–micro one. In the third investigation I attempted to illustrate the question of the optimal working time for the geometry instruction during the individual lesson, when the material was learned with the aid of programmed booklets. The question then was whether and, if so, how the lesson time was to be distributed between two different activities. For a decision on this question, practical experience indicates that at least two factors are relevant in this connection, viz. the pupils' ages and the character of the work. It was generally observed that concentration, interest and attention decline more rapidly, as a rule, in young pupils than in older ones. The need of variety makes itself felt in them more strongly and attempts should be made to obtain some form of recuperation more often for young pupils than for older ones. Of course, the character of the work also has a decisive influence on this problem. It seems reasonable to assume that activity which is interesting and meaningful to the pupils can maintain their interest at least as long as a whole lesson lasts. In many cases it is desirable that the timetable should be more flexible and thereby more adaptable to the actual conditions. On the other hand, we must assume that an interesting, varied but intensive and perhaps somewhat competitive activity, such as programmed instruction, rapidly produces in the pupils a fatigue which is perhaps not always directly noticeable during the actual lesson and only reveals itself during the subsequent lessons. There are extremely few facts available on these questions—facts based on investigations with educational material in the concrete school situation. Amongst others, Underwood (1961) has carried out a multiplicity of experiments of a theoretical character in this sphere and the results of these experiments have yielded some points of departure for the arrangement of the present investigation. The three variants which were studied as regarded the working-time-per-lesson-period variable were 15, 30 and 45 minutes. I also tried to keep under control the interval between the lessons. The experiment was carried out on five experimental groups, which underwent a programmed geometry course designed for grade 4 under the following conditions:

Group I	15-minute working period, one each day
Group II	30-minute working period, one every other day
Group III	30-minute working period, one each day
Group IV	45-minute working period, one every third day
Group V	45-minute working period, one each day

The effects of the different experimental conditions were measured with the aid of achievement tests, attitude tests and questionnaires addressed to both teachers and pupils. Three equivalent achievement tests (P1, P2 and P3) were given immediately after the end of the instructions, one month later and three months later respectively. Attitude measurements were repeatedly made in the course of the experiment, as in the experiments in parts I and II. Thus, owing to this arrangement, there were possibilities of studying the short- and long-term effects of the experimental conditions on both the achievement and the attitude sides. The initial situations of the groups were checked with the aid of attitude tests, intelligence tests and marks. On account of certain differences between the groups in the initial situation, the statistical preparation throughout took the form of covariance analysis. The following results were obtained:

1. As in the previous investigation, the programmed instruction

produces a very favourable effect on the pupils' attitudes as long as the instruction goes on. Afterwards there is a gradual fall of level and in the final situation the attitude is again "normal".

2. During the whole experiment the boys have more positive attitudes than the girls. Even though the initial situation is kept constant, we find that the boys' attitudes are clearly more positive at the end of the investigation.

3. It is only under the 30-minute condition that the pupils have an even more positive attitude during the second half of the geometry course than during the first half.

4. From the attitude point of view the optimal condition is undoubtedly one 30-minute working period each day.

5. There are no markedly different long-term effects in the attitude variable between the 30- and 45-minute conditions. For the 15-minute condition, however, there is a heavy fall in level.

6. As in the previous investigation, it appears in the achievement tests that the boys have more retentive memories than the girls.

7. From the achievement point of view a 15-minute working period produces superior effects, compared with the 30-minute and 45-minute working periods, between which there is, however, no difference.

8. In the final situation the achievement level, compared with that in the test given immediately after the end of the instruction, was significantly lower for all groups, except for the group which worked under the 15-minute condition. Thus, the retention is very good for this group, in spite of the attitude level being lower than that of any other group. A high positive attitude to the subject is neither a necessary nor a sufficient condition for good performances in respect of achievement.

On the assumption that the method of paired comparisons measures the attitude in a reliable manner, which is a reasonable expectation, bearing in mind that there is agreement, as regards results, between the questionnaire and the attitude tests, we may speculate about the practical educational consequences and the application of the results obtained. Why does a 15-minute working period produce such good effects on the achievement side and, on the other hand, such a negative attitude in relation to other groups? *One* reasonable interpretation of the negative attitude would seem to be that the pupils were exposed to recurrent frustration situations, in that they very soon had to break off an activity which they experienced as interesting, stimulating and varied. They did not have time to finish the booklet they had just commenced. Perhaps the pupils who worked under both the 30-minute and the 45-minute conditions did not have time to finish their booklets either. These pupils may have managed to finish one booklet and commenced another, but the difference is that in this case they were able to work in peace and quiet for a large part or for the whole of the lesson. One could, of course, object to an argument like this on speculative grounds and maintain that the pupils who worked under the 15-minute condition should instead have had a very positive attitude, on account of the fact that they never experienced any monotony in this connection but always had only feelings of pleasure with no accompanying gloom.

Another interpretation of the *relatively* low attitude level in the 15-minute group, which from the point of view of achievement had the best performance, could be that it is simply a question of an unusual length of time to work for, compared with conventional instruction in a subject for 45 minutes. If this is the case, there is no need to feel uneasy at the low attitude level and we may regard it as an initial but surmountable difficulty.

But if the frustration is the whole explanation of the formation of a negative attitude, should we nevertheless venture to recommend this time condition for practical use in school? What would happen if these recurring frustrations were generalized to the whole subject of mathematics and what would be the outcome, if this method—the short intensive working period with programmed material—was also applied to other subjects? The result of the investigation indicates that a certain caution is called for in this respect, as regards the use of self-teaching material. But on account of the fact that the results on the achievement side seem to be so unusually convincing in the present investigation, I would nevertheless recommend the use of a 15-minute working period in this connection. Should the negative attitude be connected with what has been said about frustration, it can be surmounted, provided that the programmed material is designed in such a way that *each separate unit of the programme can be finished within this optimal 15-minute period.*

Now that I have described, by way of summary, the most important results and briefly discussed them on the ground that they are of direct didactic relevance, I should like to give a quotation from the report of the inquiry into school working time (SOU 1967, p. 73), in which the authors strongly emphasize the need of research on these relevant questions:

> The need of extensive scientific investigations and experimental work in practical education, which is required in order to elucidate in more detail the relevant questions, is the more marked as the results of research and experiments carried out abroad cannot simply be applied in Swedish schools.

The aim of the present experiment was to make a contribution to Swedish educational research in this important sphere. Though it has been possible to shed light on certain questions by this investigation, many questions still remain to be answered.