THE INFLUENCE OF AN OPEN METHOD OF MATHEMATICS INSTRUCTION UPON THE ATTITUDE AND COMPREHENSION OF FIRST YEAR STUDENTS IN A PRIMARY TEACHERS COLLEGE

by

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ABSTRACT

This investigation reports an experimental study of the influence of two methods of intruction (open and conventional) upon the mathematics attitude and mathematics comprehension of one hundred and twenty-four first year primary teachers college students. Approximately equal numbers of first year students were randomly assigned to four groups in two experimental conditions. Sex, testing, method of instruction, and type of studentship were the major independent factors of this study.

The concepts and principles of one domain of primary mathematics content (number and numeration) were taught to the four groups of students for approximately two hours each week over a ten week period. The specially trained staff were paired for instruction. Each pair was randomly assigned to two sections of students, one in the open group and one in the conventional group. The same staff participated in both methods of instruction.

Two independent measures were used to assess the mathematics comprehension and mathematics attitude of the students. An attitude scale based on the Rasch (1960) model was especially constructed for the purposes of this study. The measures of student attitude to mathematics were obtained immediately after instruction from one half of the students in each of the experimental conditions and from all students immediately after the period of instruction.

The major hypotheses postulated higher mean comprehension and attitude scores for students who experienced the open method of mathematics instruction. These hypotheses were not supported by the data. Analyses of variance and covariance found no difference between the mean attitude scores of male and female students, direct entry and mature age students, and between pretested students and those who were not pretested. Similar results were found with the comprehension scores except for those obtained from the direct entry and mature age students. After instruction the mean comprehension score of direct entry students was significantly higher than the mean comprehension score of mature age students. A similar difference was observed between these two groups before the period of instruction. Also

after instruction, irrespective of method, the students comprehension and attitude scores were significantly higher ($p < 0.001$) than those scores obtained before the period of instruction.

Further examination of the data for each of the dependent measures by means of three-way analyses of variance and covariance was carried out. Although these procedures provided further evidence, certain limitations in the study and in the instruments qualified the findings.

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CHAPTER 1

INTRODUCTION

PURPOSE OF THE STUDY

The purpose of this study is to determine the influence of an OPEN style of instruction upon the attitudes of first year Primary Teachers College students toward mathematics.

It has been established (Johnson and Rising, 1969, p.368) that mastery of content is an essential characteristic of the 'good' or 'successful' teacher. It is generally accepted that a teacher's attitude toward mathematics influences the achievement and attitude formation of his pupils (Rosenshine, 1969). As nearly all primary teachers in both Australia and New Zealand are teachers of mathematics, it follows that a second necessary characteristic of the 'good' teacher is possession of a positive attitude toward mathematics.

The 'New' mathematics school curriculum was established to develop in the pupil a positive attitude toward mathematics as well as to facilitate pupil mastery of mathematics content. The content and attitude objectives of the 'New' mathematics curricula have generally not been realised to the extent intended by the authors of the programmes. Several writers (Alpert, Shellwagon and Becker, 1963, p.23) claim that this situation has resulted from an insufficient focus upon the instructional dimension of the new curriculum.

The discrepancy between content and attitude objectives, and actual pupil outcomes, indicates that there is something wrong with the present teaching strategies being practised in the classroom. It is the place of mathematics educators to give special attention to the development of appropriate teaching strategies. Such a development directly involves Teachers College students, and the methods by which they are trained as future teachers of mathematics.

Several methods of instruction, as alternative to the traditional (lecturing) teaching model, are available to the college lecturer of mathematics. Some of these are reviewed in this study but it appears that no single method has proved sufficient for achievement of either the mastery of content or attitudinal objectives. It is hoped that with the development of an OPEN method of mathematics instruction for the first year Primary Teachers College students, both their attitude and comprehension will improve.

This study will attempt to show that the first year students who experience an OPEN method of mathematics instruction will show significant improvement in both their comprehension of primary mathematics content and their attitude toward mathematics. An instrument which combines both the Thurstone (1927b) and Likert (1932) scaling procedures by means of a process based upon the Rasch (1960) Multiplicative Binomial Response model, will be developed to measure student attitude toward mathematics. A second instrument consisting of particular items selected from the Mathematics Progressive Achievement Test (Reid and Hughes, 1975) will be used to measure student comprehension of primary school mathematics content. The study will also attempt to show that the improvement in both student attitude toward mathematics and student comprehension of primary mathematics content is significantly greater for students who experience the OPEN method of mathematics instruction than for students who experience a conventional method of mathematics instruction.

REQUISITE CHARACTERISTICS OF THE PRIMARY TEACHER OF MATHEMATICS

Content Competence

Primary teachers who are responsible for mathematics teaching need to be competent in mathematics content if they are to be successful teachers (Johnson and Rising, 1967).

Nearly all primary school teachers in both Australia and New Zealand are general rather than specialist teachers. They are required to teach mathematics to primary pupils. If teaching consists of an attempt to bring about desirable changes in the behaviour of the pupil (Hough and Duncan, 1971; Glaser, 1962; Gage, 1964) then to effect a behavioural change the teacher nearly always draws upon content. Smith (1971) recommended that the 'various subject matters' of instruction found in school curricula also be included in Teacher Education programmes.

Several investigations have concluded that student teachers have not mastered the basic concepts of arithmetic (Todd, 1966; Dutton, 1962; Aiken and Dreger, 1961). The Committee on the

Undergraduate Programme in Mathematics (C.U.P.M., 1961; 1965) recommended that prospective primary teachers receive at least two years of college preparatory mathematics as part of their Teacher Education programme. It was also recommended that upon graduation student teachers be competent in the basic techniques of arithmetic (C.U.P.M., 1961; 1965). Unless the Teachers College mathematics curriculum develops this mastery these students will enter primary classrooms mathematically incompetent and therefore unlikely to be successful teachers of mathematics. The method of instruction is instrumental in developing the students' understanding of concepts and principles. It is significant that this report on teacher education (C.U.P.M., 1961; 1965) focuses entirely upon content and makes no recommendation with regard to methods of instruction in a Teachers College mathematics programme.

A Positive Attitude

Subject matter competence is insufficient as the sole criterion for successful mathematics teaching.

Teachers College students, as prospective teachers, should develop a positive attitude toward mathematics (Johnson and Rising, 1967). In support of this view Banks (1964, p.19) states

> The teacher who feels insecure, who dreads and dislikes the subject, for whom mathematics is largely rote manipulation, devoid of understanding, cannot avoid transmitting his/her feelings to the children.

Rosenshine (1969) has provided evidence that teacher attitude is positively related to pupil achievement. Although Biddle (1964) raises the identification difficulty concerning which teacher attitudes are related to teacher effectiveness (due to lack of agreement as to what constitutes teacher effectiveness), he does agree that positive attitudes contribute to successful teaching. Several other studies have shown that teachers who have a positive attitude toward mathematics also have a more positive effect upon the pupils than do those teachers with a negative attitude (Springhall, Whitely and Mosher, 1966; Torrance, 1966; Rosenshine, 1969). This effect is usually seen in terms of pupil achievement and pupil attitude toward mathematics (Brim, 1966; Husen, 1967; Anttonen, 1968; Ryan, 1968).

The results of a number of studies (Aiken and Dreger, 1961; Dutton, 1962, 1965; Reys and Delon, 1968) concerned with the attitudes of prospective teachers toward mathematics conclude that a significant proportion (40 per cent) of first year Primary Teachers College students does not have a positive attitude toward mathematics. Several investigators (Nagel, 1959; Rice, 1965; Yee, 1969), concerned with the large proportion of Teachers College students having a negative attitude toward mathematics, have concluded that college programmes can cause an improvement in the attitude of some students toward mathematics.

The inclusion of attitudinal objectives in a programme of Teacher Education is justified by Ray-Loree (1971), subject to the satisfaction of three criteria:

(1) The attitude identified in the objective facilitates the acquisition of teaching competencies and is characteristic of the good teacher.
(2) At least some of the student teachers do not have the desired attitude.
(3) It is possible to develop in the student that attitude specified in the objective.

It appears that the development of a positive attitude toward mathematics is an appropriate and worthwhile objective for a Primary Teachers College mathematics curriculum.

THE NEW MATHEMATICS SCHOOL CURRICULUM : INTENTIONS AND OUTCOMES

The continued entry of students into Primary Teachers Colleges with negative attitudes and non-mastery of basic mathematical concepts indicates that 'modern' mathematics programmes have failed to achieve intended outcomes. Folsom (1969, p.68) states that "...behind the New mathematics is a very real desire to have pupils know what mathematics really is". The current objectives of modern mathematics in schools include development of computational skills and mastery of mathematical ideas with an emphasis upon understanding (Johnson and Rising, 1967). There is an emphasis upon the development of pupil understanding of mathematical structure (Scott, 1972), improved understanding and the development of positive attitudes (Duncan, 1972) and the mastery of mathematical ideas (Johnson, 1967). Several major school mathematics programmes (School Mathematics Study Group or

S.M.S.G., Nuffield, Midlands, Scottish, Ball State, Illinois) advanced similar objectives and these influenced changes in both Australian and New Zealand primary school mathematics curricula.

These reforms, however, were almost totally in the content dimension of the curriculum. To the tests of computation and problem solving have now been added tests of concepts and broader problem-solving (Madden, 1966). Davis (1966) lists four needs as 'most urgent' for the improvement of mathematics education and all relate to the instructional dimension of the school mathematics curriculum.

The findings of several studies have confirmed the relative failure of modern mathematics in schools. Alpert, Shellwagon and Becker (1963) concluded that the modern mathematics programme improves neither pupil attitude nor pupil achievement in mathematics. Ruth Melson (1965), in a study of the mathematical understanding of basic concepts by student teachers, found more than two-thirds scored less than 50 per cent. Todd (1966) found little difference in either the attitude or the mathematics achievement of student teachers when comparing first year students of 1950 with first year students of 1966. Smith (1971) suggests that although the first year student of 1966 had experienced different content than did the first year student of 1950, the teaching style experienced by both was markedly similar.

A review of the literature will show that student teachers conceptualise teaching according to their own direct experiences (Shaplin, 1962). A logical conclusion is that student teachers enter college with fixed and reasonably uniform conceptualisations of the teaching process. If these conceptualisations are reinforced by the methods of instruction practised in the Teachers Colleges, there is little hope of change in the teaching style generally practised in the schools.

If methods of instruction influence pupil achievement and pupil attitude toward mathematics, it is unlikely that the objectives of modern mathematics curricula will be realised should the existing situation remain unchanged. Student teachers will continue to enter college with negative attitudes and mathematical incompetence.

ALTERNATIVE METHODS OF INSTRUCTION

Several methods of instruction are already available as alternatives to the traditional lecturing model. A college lecturer concerned with the non-achievement of mathematics course objectives might consider a different method of instruction. The selection, however, should be guided by the empirical evidence that the new method of instruction is likely to result in achievement of the specified objectives.

The Lecture Method

It has been reported (Gage and Berliner, 1975) that a great deal of teaching in tertiary institutions, including Teachers Colleges, still takes the form of a solo, expository performance. Despite a large number of studies which criticise the effectiveness of this method of instruction (Bloom, 1953; McLeish, 1968; Bligh, 1972), no study has reported the lecture to be completely ineffective.

Costin (1972) claims that the lecture method of instruction is as effective as the discussion method for student acquisition of knowledge. He argues, however, that students of lower ability are probably helped in their acquisition of knowledge by the discussion method of instruction. On the other hand, Bligh (1972) claims that lectures are as effective as other methods of imparting information but, significantly for this study, he also states that lectures are relatively ineffective for changing student attitude. Dubin and Taveggia (1968) reviewed the data of nearly 100 studies over a 40 year period and reported that nearly 50 per cent of tertiary students favoured the lecture method when compared with the discussion method of instruction. Carroll (1964) found that apart from economy and efficiency in the use of time, the lecture or expositional method combined with practice is particularly successful in teaching concepts and principles. Allendoerfer (1969) has emphasised the logical and organized structure of mathematics. From Carroll's argument it appears that the lecture method can contribute to successful student learning of mathematics.

Effective lectures need to be well organized (Skinner, 1968) and the lecturer must give careful consideration to the structure of his presentation. Gage and Berliner (1975) have conceived the lecture as a four phase structure, each component interrelated and yet distinct. For effective learning to result from a lecture presentation, the body or content phase of the total structure must be well organized (Husen, 1967). Other studies (Thompson, 1967; Bligh, 1972) are less conclusive about the effect of disorganization upon meaningful learning as an outcome of the lecture method. It is possible, however, that these findings resulted from the researchers' failure to manipulate radically the organization structure.

Ausubel (1963, 1968) has expressed the opinion that the widespread discontent with the lecture method of instruction is due in part to identification of the lecture with rote learning. Cronbach (1965, p.76-92) argues that "Didactic teaching may not be authoritarian, identified with rote learning, or condemned to occupy a strategically weak position when compared with other approaches". It appears that the lecture versus other methods of instruction debate is a meaningless one. The lecture method, in which "...the teacher gives both the principles and problem solution" (Wittrock, 1963, p.33-75), will satisfy some objectives of the college mathematics curriculum although not necessarily with all students. Hall (1974, p.58) concludes that "Some objectives are best achieved by means of a lecture, others can best be achieved by means of other methods". The situation is probably best described by Spence (1928, p.461) who stated:

> The wholesale use of lectures in college teaching can probably be decried with justification. The wholesale decrying of the use of lectures in college is just as certainly not justified.

The college mathematics lecturer concerned with the improvement of student attitude and achievement could consider the lecture as a method component, not as the only means of instruction.

Programmed Instruction

The Association of Programmed Learning (A.P.L., 1966) published a list of over 1200 programmes of instruction suitable for schools and available in Great Britain. It has been claimed (Thornhill, 1967) that programmed learning would represent one of the most significant advances ever made in teaching techniques. Such a programme is carefully structured and each student is able, theoretically, to work at his own rate through the selected sequence of content. Immediate reinforcement or remediation is provided whenever necessary at each step in the learning sequence. The sequence is carefully designed to lead the student to an ultimate goal or principle. Given time it is accepted as inevitable that the student will eventually arrive at the pre-determined destination.

It has also been claimed (Ellis, 1965) that casual or unstructured instruction in basic skills is an inefficient means of imparting concepts. Lumsdaine (1964) has claimed that the programme tries to see to it that the student does learn, and it accepts responsibility for failures. Skinner (1954) has also argued that programmed instruction provides an efficient way for learning both concepts and principles.

One of the most pervasive issues in the teaching of mathematics has been the relative effectiveness of using one or two types of instructional procedure: the 'tell and do' and the 'heuristic' (Henderson, 1963, p.1014). The 'tell and do' approach, as with programmed instruction, tends to provide the student with answer-giving instruction. Mathematics, however, is more than a series of repetitive acts. It is concerned with 'learning how to learn' (Biggs and McLean, 1969).

Programmed instruction may help the student reach a mathematical principle or concept, but even if the programme is structured as an extreme form of guided discovery, it is unlikely to teach students either the techniques of discovery or how to learn. As stated by Kersh (1969, p.251)

> A method of instruction which provides answer-giving instructions will almost certainly 'teach' a mathematics principle, but will almost as certainly not improve the learner's ability to seek answers.

A number of empirical studies in Great Britain (Corns, 1966; Stones, 1966; Buckland, 1967) has been concerned with the effectiveness of programmed instruction with student teachers. Those which report an improvement in student attitude (Buckland, Corns) were, however, not concerned with mathematics education. The study by Stones reported that less student time was required to achieve comparable learning objectives by means of programmed instruction than was the case with the lecture method.

In one informal study (Pressey, 1964), the content material of a 1100 word programme by Holland and Skinner (1961) was rewritten into a succinct statement of 360 words. The student reading time was subsequently cut from the 23 minutes needed for the original programme to a median time of 1¼ minutes. Students who merely read the short statement did as well on the follow-up test as did those students who had been through the Holland and Skinner programme.

It follows that some programmes do not use instruction time efficiently.

Hartley (1968) claims that although self-instruction is obviously an an important principle in programmed learning, learning alone may not be as effective in some situations as working in pairs or small groups. Studies of transfer effects resulting from programmed instruction (Davis, 1967; Pikas, 1967) suggest that programmed instruction is not as effective as other methods. Kenneth May (1965) reports that students do learn from programmed instruction but there is no conclusive evidence that they learn significantly more, or with greater efficiency, than from other teaching methods. He concludes that programmed instruction is incapable of eliciting the full range of behaviours included in the objectives of mathematics education, particularly those in the affective domain.

From the evidence in the literature it appears that programmed instruction as the sole teaching method is unlikely to provide adequately for student differences in mathematics curriculum. Pressey (1964) argues the case for adjunct auto-instruction. This procedure makes programmed instruction available as an alternative to the usual method of instruction. Pressey claims that experienced educators know fairly well when such a method is required, particularly in precision subjects such as mathematics and science.

The Discovery Method

In general, authors of modern mathematics programmes recommend the 'discovery' or 'heuristic' method of instruction (for example Davis, 1966; Duncan, 1972). This recommendation appears to be based upon the assumption that mathematics learning is more meaningful if the learner discovers the intended outcome of instruction for himself. Several other valued outcomes are claimed to result from this method. Bruner (1961) saw the benefits in terms of increased intellectual potency, intrinsic motivation, improved techniques or heuristics of problem-solving and inquiry. Other benefits included more personal meaning through involvement, more generic learning to promote retention and transfer power, and in its contribution to such major educational goals as problem-solving ability, autonomy, and learning how to learn. Wittrock (1966, pp.57-62) hypothesised that learning by discovery was effective in the learning of concepts and principles which have been organized into learning structures; it was effective in applying learned concepts in the learning of new concepts; and in the techniques of discovery.

Despite the claims of those who support the discovery approach (Bruner, 1961; Hendrix, 1961; Taba, 1962; Suchman, 1964) there is still considerable confusion and debate. A source of confusion is the semantic nature of the argument. There is still considerable confusion as to whether discovery refers to a method of teaching, a method of learning or 'something' that is learned (Wittrock, 1966, p.44). Biggs (1971), in an examination of the term discovery, identified different uses of the word which ranged from an extreme of complete freedom to no freedom on the part of the learner to effect a discovery. Ausubel and Robinson (1969) mention the varying levels of freedom on the part of the learner to effect a discovery. Ausubel and Robinson also mention the varying levels of teacher directedness and Keislar and Shulman (1966) report that the confusion over learning by discovery exists simultaneously at a number of levels.

Implicit in all the endeavours of clarification is the notion that some information, some instruction, is withheld from the learner. De Cecco and Crawford (1974) describe discovery teaching as that situation in which the student achieves the instructional objective with limited or no guidance from the teacher. The principal characteristic of discovery teaching then, is the amount of guidance provided by the instructor (Wittrock, 1966; Kersh, 1969). Between expository teaching, in which the principle and solution are both given, and unguided discovery in which neither principle nor solution is given, there is an intermediate area described as guided discovery. Suchman (1964) developed a theoretical model to analyse classroom communications (see Figure 1). The data in a student's mind at an instant in time, he claims, can be classified into 3 categories (facts, unifying mental constructs, and applications).

In commenting upon the Suchman model, Davis (1966) suggests that the discovery communications appeared as conspicuously horizontal channels, and rote communications as conspicuously vertical channels. Kersh (1969) suggests that it is the nature of the instructions which determines the degree of guidance given in a discovery learning situation. The provision of answer-seeking instruction and withholding of answer-giving instructions will almost certainly teach the learner a technique for identifying principles - one which applies

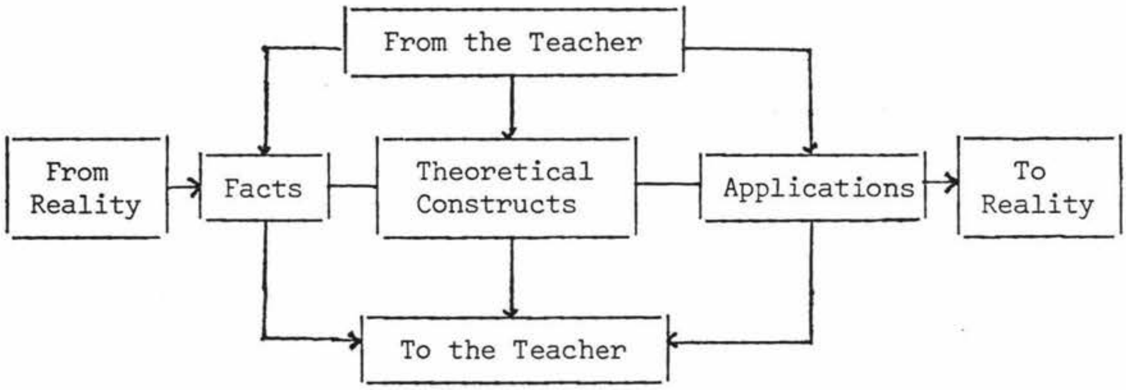


Figure 1 : Suchman Model of Classroom Communication 1964

to other problem solving situations as well. Archer (1970, p.43) reports one general set of trends is evident in many of the conclusions reached by different investigators.

> Where the criterion is initial learning of a limited number of more or less specific answers, the most highly directed groups do as well as, or better than other groups (Kittell, 1957; Kersh, 1958, 1962; Haslerud and Meyers, 1958; Worthen, 1968). Where the criterion is transfer, those groups receiving an intermediate amount of guidance, or those who derived principles from examples, perform as well as, or better than groups given both rule and answer (Forgus and Schwartz, 1957; Gagne and Brown, 1961; Wittrock, 1963b; Worthen, 1968). The results for the criterion retention are less clear. Some investigators report advantages for rule-given groups (Craig, 1956; Guthrie, 1967) and others for example-given, rule-derived groups (Corman, 1957; Wittrock, 1963a; Guthrie, 1967).

There must be some caution with such generalisations, for many variables of the different researchers are not equivalent. A major difficulty encountered by researchers, is the problem of comparison in guided discovery situations. It is not an easy task to maintain an equivalent degree of guidance in different experimental situations.

The literature is scarce with regard to the effect of a discovery method of instruction upon student attitude. Worthen (1968a) administered a semantic differential and a statement attitude scale to discovery and expository groups. No significant differences were found between the groups. Ausubel (1963) has argued that discovery methods are more appropriate to children under 12 years, within Piaget's cognitive stage of concrete operations, than to older pupils and tertiary students since the latter can learn by meaningful reception.

The outcomes of learning by discovery and teaching for discovery remain a vague hypothesis. There is evidence that some students will benefit as a result of this method of mathematics instruction either in terms of achievement, in terms of attitude, or in terms of broadening their conceptualisation of the nature of the teaching processes. An argument does exist for discovery teaching to be included as an integral component of the mathematics curriculum for Primary Teachers College students. If College teaching staff analyse rigorously their instructional techniques to identify the particular behaviours each technique may be expected to elicit, it might be possible to predict the learned outcomes of instruction more accurately.

> It might also result in a criticism of those who label methods of instruction 'the discovery method' or 'the lecture method' and who evaluate them good or bad accordingly. (Kersh, 1965, p.253)

Mediated Instruction

Manipulative materials: Although the term "instructional media" is frequently associated with sophisticated electromechanical devices, Erickson (1965) makes a distinction between old or traditional media and those more recently developed. Many writers who discuss direct and structured experiences for the learning of mathematical concepts, emphasize the importance of traditional media in the form of manipulative materials (Mariani, 1959; Stoebe, 1960; Johnson, 1962; Suppes, 1964; Carlson and Tillman, 1967).

Mathematics learning is in part concerned with the development of operational understanding. Psychology laboratories specialising in child development report from Geneva that an operation is *something* that can be performed externally with concrete materials, or internally with symbols which represent those materials. Piaget (1952), Bruner (1960) and Flavell (1963) have demonstrated that the probability of a consistent and accurate performance of internal operations is increased by repeated experiences with external concrete models.

Donald Nasca (1966), in a controlled experiment with Grade 2 groups using Cuisenaire materials, found that they were able to demonstrate competence in skills beyond those normally developed at that level. Dienes (1963) suggests that at any level, mathematical concepts are internalised as the result of a three phase process. During both the introductory 'play' stage and the secondary or 'becoming aware' stage, he recommends that where possible the student actively manipulate structured materials. The physical form of these materials is such that particular concepts and relationships are exemplified in a concrete manner.

David Clarkson (1970), discussing the Cambridge Conference report on the correlation of Science and Mathematics in schools, notes the recommendation that student teachers should work in their college courses with manipulative materials of the type being developed in new curriculum projects. Meaningful mathematics teaching is, in part, dependent upon the mathematical capabilities of the classroom teacher. Meaningful teaching is more likely if the teacher understands the structure of elementary school mathematics. Several investigations have found that a large proportion of prospective primary teachers lack an understanding of the basic concepts in mathematics (Grossnickle, 1951; Dutton, 1962; Antonnen, 1968). In a review of methods used in the mathematics education of teachers, Hartung (1955) recommended that student teachers learn the structure of mathematics with the help of 'Multisensory' aids. A group of mathematics educators in England (Mathematics Section of the Association of Teachers in Colleges and Departments of Education, 1970) urged the development of mathematics courses in primary teacher education which would emphasize the use of structured materials in problem-solving situations.

Student teachers are now encouraged to record basic mathematical computations using a variety of methods or algorithms. Quast (1972) discusses a multiprocedural approach in the preparation of primary mathematics teachers. He urges the use of concrete and semi-concrete materials to develop an understanding of the various algorithms used in computation. Dienes (1965) has developed a set of concrete materials (Attribute Blocks) to assist students to understand logical operations. Students are encouraged to manipulate physically the Attribute Blocks in concrete situations, before coding and symbolic reasoning.

It is evident that a Teachers College mathematics curriculum, concerned with developing student understanding of mathematical structure, will be more likely to achieve such an objective if students are encouraged to use structured and manipulative materials in their learning activities.

New media - Television and teaching machines: In terms of teacher economies, television is of significant value. This medium enables the process of instruction to simultaneously reach an audience of unlimited size. It is also of value in the analysis of classroom communication.

There is, however, a wealth of evidence suggesting that there is no significant difference in the amount learned from direct and televised instruction (Carpenter and Greenhill, 1955; Dreher and Beatty, 1958; Macomber and Sigel, 1960). Research indicates that increasing amounts of both audial and visual information do not necessarily lead to greater learning (Travers, 1964). There is no evidence to suggest that televised instruction will cause an improvement in the attitude of students toward mathematics. Possibly the only advantages from such instruction are the variations it can provide from time to time and teacher economy.

The impact of the computer upon Primary and Teacher education has not yet been felt in either Australia or New Zealand. Considerable research into Computer Assisted Instruction needs to be undertaken. The chief unsolved technical problem is how to reduce the cost sufficiently to make Computer Assisted Instruction within the budgets of schools and Teachers Colleges.

> One of the initial temptations is to dazzle the student with an array of visual and auditory stimuli which serve more to impress him with the capabilities of the computer than to provide him with the necessary instruction. (De Cecco and Crawford, 1974, p.400)

Each individual student enters a learning situation with a different background of experiences. Stolurow and Davis (1965) point out that Computer Assisted Instruction promises to be the best means by which provision is made for these variations. It is unrealistic, however, to expect that the individual learning requirements of students will be best met by any one teaching method. Gentile (1967) indicates that several realistic considerations make provision for such individual differences a difficult educational feat. There are many kinds of student differences in mathematics and not all of them can be accommodated by allowing the computer to generate sequences on the basis of student response.

As yet there is no empirical evidence that Computer Assisted Instruction is more or less effective in improving student attitude toward mathematics than is any other method of instruction.

Traditional media: There are several conventional devices which act as a middle condition of instruction between the student and what he is to learn. If variation acts as a stimulus to mathematics learning, then mathematics educators will employ a number of media-assisted experiences in their programmes of Teacher Education.

Extensive use can be made of models and graphic materials in the teaching of mathematics. Models are simplified representations of reality and assist the student with his conceptualisations. Cuisenaire rods, Multibase Arithmetic Blocks and the Abacus, model the structure of numeration systems. Three dimensional representations permit the student to explore concretely spatial relationships. Graphical representations are used to effect various data-set comparisons. Motion pictures, slides, projectuals and filmstrips, as adjuncts to the instructional process, provide variation. Very often traditional media project mathematical concepts with greater clarity, novelty or realism than can an instructor limited to the chalkboard.

It seems likely that a Teachers College mathematics curriculum will utilise media assistance no matter what the method of instruction, if only for the reasons already mentioned.

TEACHER EDUCATION : MATHEMATICS INSTRUCTION

The lecture is still a widely practised method of instruction in Teacher Education. As with alternative methods that are available to College staff, this strategy alone does not satisfy all of the intended outcomes of the mathematics curriculum. Two significant outcomes are yet to be adequately achieved: student mastery of primary school mathematics content, and the development of a positive student attitude toward mathematics.

It can be argued that if no one method of instruction can appropriately satisfy these objectives then a 'multi-method' process of instruction needs to be developed. A process which incorporates a variety of instructional methods is more likely to result in the achievement of intended outcomes, considering individual student differences.

The mathematics laboratory is one source of a multi-method approach. In a laboratory students usually work in small groups on activities requiring the physical manipulation of instructional materials. This, however, is not the sole procedure characteristic of the laboratory method. It is possible for the laboratory technique to separate from, integrate into, or correlate with other methods of instruction. Vance (1969) investigated a laboratory programme which functioned as an adjunct to the regular method of instruction. It was found that although student achievement and attitude toward mathematics were not affected, student reaction was more favourable to the laboratory setting than to the traditional setting. Wilkinson (1970), using an integrated approach, found that student attitude toward mathematics was not affected but he noted cognitive gains with students of relatively low intelligence. In a year-long study, Johnson (1970) concluded that students taught exclusively by an activity approach did not perform as well as did students who had received textbook-based, activity-enriched instruction. Wasylyk and Kieren (1971) organised a mathematics laboratory which incorporated several methods of instruction. Results of this study indicated significantly higher achievement, and significantly higher attitudes toward mathematics, for the experimental group compared with students in the traditional setting.

The outcomes of research into teaching methods have often been inconclusive, and for many possible reasons. Operational definitions vary from study to study, criterion measures vary with experimental treatments, assumptions about subjects vary and so do the theoretical frameworks and research designs. McKeachie (1961, p.48) suggested that "...students who profit from one method of instruction may do poorly in another, while other students may do poorly in the first method but well in the second".

The research evidence suggests that a process of instruction which includes a variety of methods of instruction is likely to be more effective in improving student attitude and achievement than is a process which consists only of a single method of instruction.

AN OPEN METHOD OF MATHEMATICS INSTRUCTION

It appears that the provision of a variety of instructional styles is the essential characteristic of an appropriate mathematics curriculum. In order to provide variety it may be necessary to offer simultaneously several diverse methods of instruction.

A building design which permits flexibility (simultaneous group work, individual work, lectures, manipulative activities, media assistance) will facilitate the operational phase of a multi-method pattern of instruction. An improved mathematics curriculum will also offer the student a choice in the direction of his learning. Individual student needs vary and in order to master basic mathematics content, each will need to specialise in different content areas of the curriculum. It is neither essential nor instructionally effective for all students to progress through identical areas of content at the same pace. Within the specified content areas of the mathematics curriculum there needs to be a variety of learning activities, some with media assistance and others requiring the use of manipulative materials. The College mathematics 'lecturer' needs an organisational structure, for it has been shown that students new to a multi-method approach seem to need fairly specific instructions that include not only how they are to proceed, but provide feedback relative to their progress (Bruner, 1966).

Flexible scheduling is another essential characteristic of an improved or OPEN mathematics curriculum. For OPEN methods to succeed, administrative and organisational procedures must themselves be open. Although some writers have expressed concern with any trend in education which moves away from a very structured curriculum (Friedlander, 1965; Toost, 1973), it appears that the intended outcomes of improved student attitude and mastery of content are more likely to be achieved if the process of instruction is OPEN.

This study will attempt to determine the influence of an OPEN method of instruction upon the mathematics attitude and mathematics comprehension of first-year Teachers College students.

CHAPTER 2

REVIEW OF THE LITERATURE

INTRODUCTION

During the past fifteen years mathematics educators have been particularly active in producing mathematics programmes designed to improve pupil understanding and pupil attitude toward mathematics. A review of research studies (Aiken, 1970) provides evidence that modern mathematics curricula are not achieving either objective as had been intended. From the literature reviewed by Aiken (1970) it is evident that a large proportion of students enter Primary Teachers Colleges with negative attitudes toward mathematics and a mathematical incompetence. These students will enter primary classrooms as teachers with the same attitude and incompetence unless an improvement results from the Teachers College mathematics curriculum.

In order to achieve that improvement, mathematics educators in Teachers Colleges need to design appropriate curricula. Such a design results in part from the precedent considerations given to the selection of objectives. Should specified outcomes be intended, these objectives then influence the curriculum design. This design is more likely to be appropriate when curriculum strategists possess a clear conception of the constructs specified in the objectives. If one of the specified objectives expresses an intention of improving student attitude toward mathematics, then an appropriate curriculum is more likely to result from those strategists who possess a clear conception of the 'attitude' construct. This review will investigate theories that relate to conceptual definitions of the mathematics attitude construct. If it is also intended that the curriculum change existing student attitudes toward mathematics, strategists will require some understanding of theories that relate to the process of attitude change. This review will investigate some of the theories that relate to attitude change.

The interpretation of results regarding curriculum effectiveness depends to some degree on the types of measuring instruments or techniques employed in the evaluation. The mathematics-attitude construct has been made operational in a number of ways. This review will examine some of these measuring techniques and particular attention will be given to a technique developed by Rasch (1960) and extended by Andrich (1976).

The organisation and integration of learning experiences and subject content into a method of instruction is a significant component of any curriculum. Wheeler (1967, p.30) identifies "...the organisation and integration of learning experiences and content with respect to the teaching-learning process within school and classroom" as the fourth phase of his five-fold curriculum. If no single method of instruction has proved successful in achieving the intended outcomes of mathematics curricula, will an OPEN strategy, which includes a variety of different methods, be more likely to succeed? Another significant component of a mathematics curriculum is the selection of the subject's content (Taba, 1962; Wheeler, 1967; Kerr, 1968). The mathematics content in current primary school curricula will influence the selection of content in a Teachers College mathematics curriculum. What is the mathematics content in school curricula and what additional criteria must be observed when this phase of the college curriculum is being determined?

This review will attempt to answer these questions and in addition will present research evidence related to the mathematics attitudes of pupils and student teachers. The findings will be of assistance to strategists engaged in the process of developing an appropriate mathematics curriculum for Teachers College students.

First this review will examine some of the theories concerned with the nature and structure of the attitude construct as it relates to the student's attitude toward mathematics. Second, operational definitions and methods of measuring attitudes toward mathematics will be presented. Third, theories and empirical studies pertaining to attitude formation and change are reviewed. Next, the concepts of open education and open methods of instruction are considered. The final section examines those determinants influencing the selection of mathematics content for a Teachers College programme.

THE NATURE AND STRUCTURE OF ATTITUDES

Judged by the frequency with which the attitude construct occurs in the literature, it may indeed be the most indispensable concept in social psychology. The operational meaning of a construct is acquired through its definition in terms of a set of operations. The concept of an attitude may be defined by a particular set of operations involving the design, administration and scoring of an opinion questionnaire (Himmelfarb and Eagly, 1974). Several different sets of operations may be used to define the concept of an attitude and it has been said (Campbell and Fiske, 1959, p.81; Cook and Selltiz, 1964, p.37) that a variety of operational definitions for a single construct may be a desirable feature, but questions do arise as to whether differing sets of operations define the same construct. The conceptual definition of a construct, however, refers to its meaning within an abstract theoretical system.

Conceptual Definitions

When the term attitude was first used in relation to social phenomena, it was natural to conceive of an attitude as a "...tendency, set, or readiness to respond to some object" (Allport, 1935, p.798). This readiness view implied that an attitude predisposed an individual to particular behaviours which he would not have actioned had that attitude not been acquired. The readiness view inferred that there was an implication of heightened responsiveness to arousal (Newcomb, 1959, p.384). Campbell (1963) has criticised this readiness conception of an attitude on the grounds that it ignored a distinction from habit. In order to make that distinction, some writers (Thurstone, 1931; Allport, 1935) emphasized the motivational and affective character of attitudinally-induced behaviour. Krech and Crutchfield (1948) distinguished attitudes from beliefs. Attitudes contained affect, whereas beliefs were affectively neutral. Doob (1947) distinguished knowledge from attitude. Whilst both mediate responses, only an attitude has a drive-producing quality that causes it to energize and produce behaviour. There is, then, a relationship between an attitude and behaviour. It has been suggested (Fishbein, 1967; Lott and Lott, 1968; Staats, 1968) that an attitude has an evaluative dimension. This concern with the evaluative nature of attitudes was of interest to Katz and Stotland (1959, p.423) who defined an attitude as "...a tendency or predisposition to evaluate an object or symbol of that object in a certain way". Evaluation assigns a degree of preference within bi-polar extremes on a linear continuum. Oppenheim (1966) accepted that an attitude was an abstraction, but the response-set to a stimulus, or set of related stimuli, reveals an intensity of preference for one of the bi-polar extremities. Such a model perceives attitudes as sets of straight lines running from positive through neutral to negative feelings about the object or issue in question.

An attitude may also be thought of as a "component-construct" (Katz and Stotland, 1959, p.423). This view regards an attitude as consisting of three components: a cognitive component which induces an individual to think in a certain manner when confronted with a particular stimulus; an affective or feeling component, and a behavioural or action component. Several writers (Katz and Stotland, 1959; Krech, Crutchfield and Bellachy, 1962; Newcomb, Turner and Converse, 1965; Triandis, 1971) used this tripartite viewpoint to try and deal with important problems of attitude structure such as the interrelations between throught, feeling and action. There are problems, however, in "...differentiating the various components either logically or operationally" (Fishbein, 1967a, p.257).

Most studies concerned with either student teacher or pupil attitudes toward mathematics use the term attitude to refer to any reports of what the subjects of the study feel, or think, or the ways in which they intend to act. Instruments such as those of Dreger and Aiken (1957), Shapiro (1962) and Shaw and Wright (1967) are designed to make operational the attitudes of student teachers or pupils toward mathematics. These instruments contain items which can be attributed to at least one of the three attitude components. Some of their instrument items can simultaneously refer to more than one of the attitude components. This is a problem if the research study is concerned with the effect of attitude determinants.

Recent writers (Keislar, Collins and Miller, 1969; McGuire, 1969) have avoided the issue of conceptualisation of an attitude, "with justification" (Himmelfarb and Eagly, 1974, p.6). There is a decided lack of empirical evidence on which to base a broad integrative theoretical system.

Operational Definitions

The concept of attitude has been made operational in a number of ways, but most studies employ some kind of questionnaire to measure attitudes. These questionnaires usually assess attitudes through self-reports of opinions and beliefs, or feelings, or evaluations or of behaviour.

Thurstone's method (Thurstone and Chave, 1929): Some studies investigating the attitude of Teachers College students employed a Thurstone-based design. Dutton (1962) constructed a 15-item scale to measure the attitude of prospective primary teachers toward mathematics and found that 38 per cent of the 127 subjects had an unfavourable attitude toward mathematics.

Thurstone defined the concept of a discriminal process with respect to the affective properties of statements. Measurement of a respondent's attitude on the topic is the mean or median of the scale values of the items he has endorsed. The scale value of an item is the median of the number values assigned to that item by a panel of judges. The number values are pre-determined and presumed to be equally spaced on a continuum ranging from extremely favourable to extremely unfavourable. The fundamental design for judges to obtain the relative affective value of an item is the method of paired comparisons (Thurstone, 1927c).

A criticism of the Thurstone procedure relates to the process of item-value determination since the procedure of assigning a number value to a specific item cannot be regarded as a value-free act. The value position held by any judge will be reflected in the number value assigned to an item. This number value is therefore not necessarily consistent with the sample population's estimate of the value of that item.

The Likert technique: Likert (1932) and Murphy and Likert (1937) developed an alternative procedure for the quantification and study of attitudes. To construct a Likert scale, a large number of opinion items is collected and classified according to whether the item is favourable or unfavourable toward the attitude object. This categorisation is made by means of a pilot study and subsequent item analysis. The respondent whose attitude is to be measured is asked to indicate to what degree he agrees or disagrees with each item. Usually five catetories of intensity are provided for each item. Both Thurstone and Likert reject the view of Krech and Crutchfield (1948) that beliefs are neutral in affect. The Thurstone and Likert scales essentially infer a person's attitude from his reports concerning his beliefs. The view of Fishbein (1967c) that a person's belief about an attitude object determines his overall evaluation of it, is fundamental to their processes of attitude measurement.

Several studies investigating the attitude of prospective primary teachers toward mathematics used the Likert technique for construction of their attitude scales. Adams and Von Brock (1967) devised a 35-item mathematics attitude scale based on the six attitudinal levels of the Taxonomy of Educational Objectives (Bloom, Englehart, Furst, Hill and Krathwohl, 1956). Shaw and Wright (1967) included two Likert scales for the measurement of attitudes toward mathematics, and Alpert, Shellwagon and Becker (1963) have described the Likert-type attitude scales used in the National Longitudinal Study of Mathematical Abilities (NLSMA) of the Stanford-based School Mathematics Study Group. Aiken (1970, p.554) reports that "...many researchers have preferred Likert-type scales to measure attitude toward mathematics because they are usually easier to construct than Thurstone or Guttman scales".

A criticism of the Likert procedure refers to the attitude-score distribution of the sample population. Attitude scores are transformed to measurements but these measurements are not independent of the attitude distribution of the sample population. The attitude measurement obtained for a particular score is not necessarily constant for different sample populations.

Semantic Differential: Osgood, Suci and Tennenbaum (1957) developed the Semantic Differential to measure attitude. Respondents to a Semantic Differential attitude scale rate the attitude object on a series of bi-polar adjective scales. For example, a student's direct evaluations of 'mathematics' may be obtained by having him rate that concept on bi-polar scales such as good-bad, pleasant-unpleasant, like-dislike. These measures provide direct self reports of feelings and evaluations of the attitude object.

Antonnen (1968) used a Semantic Differential attitude scale to measure student attitude toward mathematics. He reported moderate correlations of mathematics attitude scores with standardised test scores in mathematics. Achievement was greater for those students whose attitudes were favourable toward mathematics.

Guttman scale: The items in a Guttman scale have the properties of being ordinal and cumulative (Oppenheim, 1966). This technique, which enables a researcher to know exactly those items that have been endorsed from a respondent's score, was used by McCallon and Brown (1971) to determine student attitude toward mathematics.

Evaluation of the Common Operational Techniques

Most of the previous methods that operationalise the attitude construct require a respondent to express some degree of favourability-unfavourability (Fishbein, 1965, 1966, 1967c). This justifies the contention that attitudes should be regarded as synonymous with evaluative meaning (Katz and Stotland, 1959). An important study (Tittle and Hill, 1967) compared the effectiveness of various types of attitude scales (Likert, Thurstone, Guttman and Semantic Differential) in predicting objective indices of 'voting behaviour'. The Likert scale was superior to all other scale types. It yielded a mean correlation coefficient of 0.54 with the objective indices of 'voting behaviour'.

One problem when making comparisons of this type, particularly with the Likert and Thurstone procedures, is that although the Thurstone methods were seen to scale items, they apparently were not understood to have any direct consequence for the quantification of attitude. Conversely, although the Likert method was seen to quantify attitude, it was not apparent how it had any consequence for the scaling of items (Andrich, 1976).

Attitude scales described in the reviewed studies of student attitude toward mathematics are not considered appropriate for this investigation. The attitude domains are usually not concerned with either the content or teaching of primary school mathematics. Neither the Likert nor Thurstone procedures appear sufficient as a means of measuring attitude. An operational technique which combines both the Likert and Thurstone procedures appears to be an improvement on each of these separate processes. Such a development will provide both an attitude score for each subject and an estimate of the mathematical affectivity of each item used in the attitude scale. The more affective items would tend to be endorsed only by those subjects who score highly over all of the items in the attitude scale.

The Rasch Model

The Rasch psychometric model, called the Multiplicative Binomial, provides a perspective for unifying the Thurstone procedure for item scaling and the Likert procedure for attitude measurement. Both the affectivity of an item and the attitude of a person, which are presumed to be the two prime determinants of the response a person makes to any item, are parameterised in the model, and from a given body of data, both sets of parameters are estimated (Rasch, 1966; Rasch and Stene, 1967; Anderson, 1972).

With respect to item scaling, the formulation subscribes to Thurstone's general requirements, in particular that the derived parameter estimates should be independent of the attitude characteristics of the sample used for obtaining these values. In the Multiplicative Binomial model, the attitude of a subject is formalised since his responses to the items are dependent upon his attitude, but the structure of this model is such that the unknown subject parameters do not affect the estimates of the item parameters (Andrich, 1976).

With respect to the measurement of subject attitudes, the consequences of the model are initially the same as in the Likert scoring, namely that the integral values for the response categories endorsed by a subject are simply assumed to indicate a subject's attitude. However, with the Multiplicative Binomial model, these total scores are subsequently transformed into measurements, and in contrast to standard errors of measurements which follow from reliability indices used in the simple Likert procedure, the precision of measurement is estimated independently of the attitude distribution of any sample. Although there are no reported studies concerning the measurement of student attitude toward mathematics which use this technique, the Rasch process does provide the advantage of obtaining simultaneously estimates of both item-affectivity and subject-attitude parameters. As both estimates are of the same dimension, it is possible to compare particular items with particular attitude scores. As a consequence it is possible to predict from a subject's attitude score those items he is likely to have endorsed.

THEORIES OF ATTITUDE FORMATION AND CHANGE

This study is concerned with the effect of an OPEN method of mathematics instruction upon student attitude and mathematics comprehension. It will be shown that student attitude toward mathematics is in need of improvement. The study will examine theories that relate to attitude formation and change. A number of theories has been proposed to explain attitude formation and change. This study reviews broadly some of these theoretical positions.

Cognitive Consistency Theories

In general, cognitive consistency theories (Heider, 1946, 1948; Osgood and Tannenbaum, 1955; Rosenberg, 1956, 1960; Festinger, 1957) are concerned with inconsistencies that arise between related beliefs, segments of knowledge, and/or evaluations about an object or an issue (Himmelfarb and Eagly, 1974). The various consistency theories (Balance theories, Congruity theories, Affective-Cognitive theory, Dissonance theory) differ in several respects but all have in common the idea that inconsistency is unpleasant, and that the psychological tension created by this unpleasant state leads to attempts at reducing the inconsistency. Attitude change is one important way in which inconsistency is reduced.

Learning Theory Approaches

Consistency theories begin with an existing cognitive structure. They then concern themselves with the changes that occur in the structure as a result of inconsistency within the existing structure, or between new elements and the structure (Himmelfarb and Eagly, 1974). How does the existing cognitive structure first become established? One answer given is that attitudes are learned (Hovland, Janis and Kelly, 1953; Rhine, 1958; Weiss, 1962, 1968; Fishbein, 1963, 1967b; Bem, 1965, 1972; Staats, 1967, 1968). Generally speaking the various learning theory approaches differ according to the theorist's conceptualisation of the process of learning. There may, however, be important differences when a standard learning paradigm is applied to attitudinal problems. Most of the learning approaches to attitude formation and change are in need of additional theoretical development.

Social Judgement Theory

Early studies in the Yale research programme (Hovland, Janis and Kelly, 1953) indicated that certain variables which influenced attitude change also affected judgements. It has been found (Kelman and Hovland, 1953) that messages from highly credible sources not only produced more opinion change but also were judged to be more fair and unbiased than messages from sources of low credibility. Sherif and Hovland's (1961) theory of social judgement attempts to explain how existing attitudes produce judgemental distortions of attitudinally-related objects, and how these judgements mediate attitude change.

The theory, however, has remained vague as to the exact relationship between judgement displacements and attitude change (Himmelfarb and Eagly, 1974).

Functional Theories

Functional theories (Katz, 1960; Kelman, 1961) consider how attitudes and efforts to change attitudes are related to the motivational structure of the individual. These theories focus on the meaning of the influence situation in terms of both the kinds of motives that it arouses and the individual's method of coping and achieving his goals. Katz (1960, p.170) defined four functions that attitudes may serve for an individual:

(i) An instrumental or utilitarian function which recognises that people are motivated to gain reward and minimise punishment;
(ii) A knowledge function based on the individual's need to maintain a stable, organised, and meaningful structure of the world;
(iii) An ego-defensive function based on the individual's need to protect himself from his own unacceptable impulses, or from facing threats in the external world;
(iv) A value expressive function that takes into account that attitudes are held because they express or enhance self-identity.

An understanding of these functions is important for attitude change procedures since a particular method may produce change in individuals whose attitude serves one particular function, but may produce no change, or even change in an opposite direction, in individuals for whom the attitude serves a different function.

Conclusion

The building of general models of attitude change is not the major current direction of work in attitude change. Most of the newer theories (McGuire, 1962; Bem, 1965; Janis, 1967) encompass only a limited range of phenomena. Although limited range theories are of growing importance, Himmelfarb and Eagly (1974b) report that the traditional theories of attitude change have not been ignored.

Although an effective general theory of attitude change is yet to evolve it is apparent that attitude transformations result from many diverse situations. It appears that multi-methods of mathematics instruction which establish diverse learning situations are more likely to succeed in changing the mathematics attitude of student teachers. A curriculum designed to improve student attitude toward mathematics is likely to be more effective when a number of instructional methods is employed than is a curriculum which uses only a single method of instruction.

EMPIRICAL INVESTIGATIONS

General Studies

A number of studies (Collis, 1950; Plant, 1958; Rabinowitz and Rosenbaum, 1960; McLeish, 1969) have examined the attitude changes of student teachers which resulted during the course of their professional training. Although the question has been raised by Shipman (1967) that the response of students to items contained in an attitude scale is not congruent with their beliefs, there is evidence that student attitudes do change as a result of their college courses (Cox, 1960; Leton, 1961; Brim, 1966).

A major study by McLeish (1969, p.23), investigating student attitudes in ten colleges of education in Great Britain that had a combined annual intake of over 1600 students, found:

(i) Mature age students changed in some areas but neither in basic personality structure nor in personal values.
(ii) Direct entry students on three-year courses showed significant changes in the areas of educational and social opinion.

If students have negative attitudes toward mathematics the research findings have suggested that college courses can modify those attitudes. McLeish's study suggests that the most significant changes in attitude are likely to occur with direct entry students in a three-year course of Teacher Training.

Mathematics Studies

During the past fifteen years, Dutton (1962, 1965) and others such as Reys and Delon (1968), have conducted a number of studies concerned with the attitude of prospective primary school teachers toward mathematics. In a survey at the University of California, Los Angeles, Dutton (1962) found that 38 per cent of 127 elementary education majors had unfavourable attitudes toward mathematics. More recently, Reys and Delon (1968) reported that only 60 per cent of the

385 University of Missouri education majors whom they surveyed had favourable attitudes toward mathematics.

Several studies (Dutton, 1962; Smith, 1964; White, 1964) have investigated the reasons for student teachers' dislike of mathematics. Some of the reported reasons are associated with stimulus variables (moral problems, boring work, inadequate teachers) and some with response variables (failure to understand, and fear). There is a number of factors which lead to a pupil's negative attitude toward mathematics: attitude, repeated failure, and peer attitude all have an effect. In a study concerned with pupil attitude toward mathematics, Banks (1964) found that the most significant contributory factor was the attitude of the teacher toward mathematics. In support of this, after reviewing 65 articles and research investigations, Aiken (1970) concluded that one of the most important factors affecting pupil attitude is the teacher's attitude toward mathematics. Student teachers with these or similar reasons for a dislike of mathematics are not few in number. Aiken (1970) estimates that approximately one-third of student teachers express a dislike for mathematics. An implicit aim of pre-service Teacher Education is the adequate preparation of students to become, in the near future, effective primary school teachers.

It appears that one characteristic of effective teachers is the endeavour to maximise 'learning' for each individual pupil in his classroom. Several writers (Glaser, 1962; Gage, 1964; Carroll, 1965; De Cecco and Crawford, 1969) have emphasised pupil learning as an outcome of effective teaching. Next, the problem of the influence of the teacher's attitude upon pupil learning will be examined.

The Influence of the Teacher's Attitude

It is generally held that teacher attitudes and effectiveness in a particular subject are important determinants of pupil attitudes and performance in that subject (Biddle, 1964; Rosenshine, 1969). Torrance (1966) studied 127 sixth through twelfth grade mathematics teachers who participated in an experimental programme to evaluate 'School Mathematics Study Group' materials. The result showed that teacher effectiveness had a positive effect on pupil attitude toward teachers, methods, and school climate. Garner (1963), in a study of the relationship between teacher attitudes and pupil attitudes toward mathematics, found the following:

(i) There is a relationship between teacher background in mathematics and pupil achievement.
(ii) There is a relationship between teacher attitude toward mathematics and pupil attitude toward mathematics.
(iii) There is a relationship between teacher attitude and changes in the pupil's attitude toward mathematics.

Peskin (1965) found more complex relationships. He found significant correlations between teacher understanding of mathematics and both pupil understanding and pupil attitude. However, he also found an interactive effect between teacher understanding and teacher attitude: teachers with a 'middle' attitude and a 'high' understanding had students with the best scores in geometry, but teachers with 'low' attitudes and 'high' understanding had students with the poorest achievement in arithmetic and geometry.

Assuming that teacher attitudes can be communicated to pupils and can affect the attitudes and performance of pupils, it is significant for this study to ascertain whether college courses concerned with student mastery of mathematics content can improve the attitudes of students toward mathematics.

The Influence of College Courses

Already several studies have reported that it is possible for college courses to affect attitudes of Primary Teachers College students (Cox, 1960; Leton, 1961; Brim, 1966; McLeish, 1969). Other studies such as those of Purcell (1965), Dutton (1965), Todd (1966) and Gee (1966), have investigated the effect of college mathematics courses upon student attitude. All report a noted improvement in student attitude following completion of the courses. One study (Gee, 1966) measured both the mathematics comprehension and mathematics attitude of 186 prospective primary teachers before and after a college mathematics course. The following results were reported:

(i) There was a significant improvement in attitudes toward mathematics and a gain in basic understanding of mathematics by the students while they were enrolled in the course.
(ii) A positive correlation was found between pre-test attitude and final grades.
(iii) No correlation was found between pre-test attitude and a change in understanding mathematics.
(iv) No correlation was found between changes in attitude and changes in understanding of mathematics.

Conclusion

A review of the literature has suggested that the affective objectives of school mathematics programmes are more likely to be realised if classroom teachers hold positive attitudes toward mathematics.

An appropriate Primary Teachers College mathematics curriculum can improve the student teacher's attitude toward mathematics. Provided the student teacher maintains the improvement in attitude, there will then be an increase in the number of teachers entering primary classrooms with a more positive attitude toward mathematics. More effective mathematics teaching will result from this improved situation.

OPEN EDUCATION

The Movement

The Plowden Report (Plowden, 1967) in England brought to the attention of the educational community that OPEN methods of instruction had effected a significant 'climatic' change in the classrooms of British primary schools. Journalists such as Silberman (1970) and Featherstone (1971) praised these British programmes, and other writers presented the philosophy, practice, psychological foundations and presumed effects of these "open" education programmes (Cazden, 1969; Barth, 1970; Rathbone, 1972).

The writings of Featherstone (1967a, 1967b, 1967c), Bassett (1970) and Cameron (1972, 1973) reported the changes that had occurred in British primary education to the education communities in America, Australia and New Zealand. Soon afterwards open education began to appear in schools in these countries.

Conceptualisations of Open Education

"There is no agreed-upon systematic theory existing among 'OPEN' educators today, for within the general orientation there is room for considerable difference in style and practice" (Hogben, 1974, p.225). The difficulty in obtaining a systematic theory, or concise definition, is highlighted by Bussis and Chittenden (1970) who refer to the 'NON MODEL' of open education. There is no single document to which one can turn to discover what open education really is. Bussis and Chittenden do, however, propose a two dimensional space or double classification scheme for conceptualising learning environments (see Figure 2).

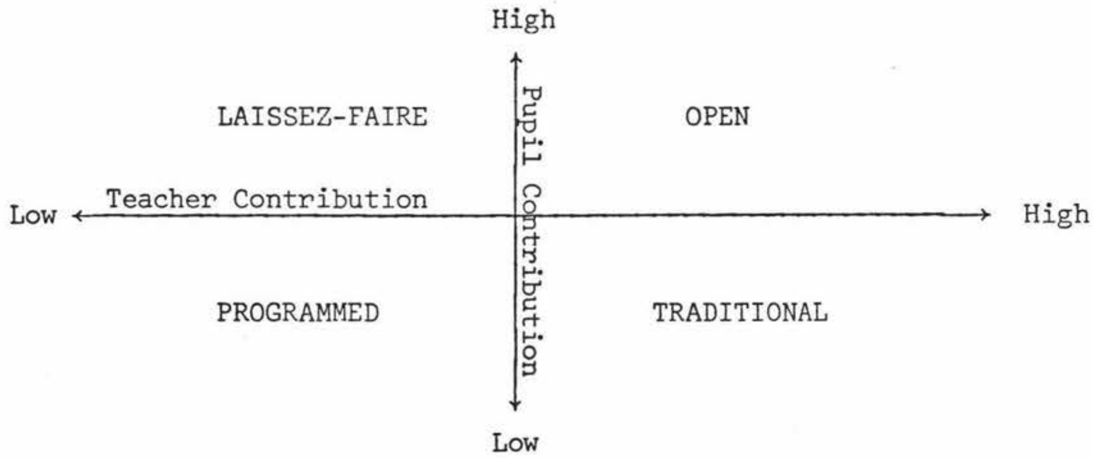


Figure 2 : Classification of Learning Environments (Bussis and Chittenden, 1970)

From their representation, open education can be viewed as an environment in which there is a high level of contribution from both teacher and pupil.

Walberg and Thomas (1972, p.198) reiterate the difficulty of characterising open teaching in the manner that behavioural scientists are accustomed to when operationalising concepts. They claim that the approach "...is founded upon contingency and uniqueness, each pupil, teacher, and event is *sui generis*". Open teaching does differ from teacher-centered, pupil-centered, and programmed text or other material-centered approaches. It combines all three, with both the teacher and the student determining the goals, materials and activities (Gardner and Cass, 1965; Plowden, 1967; Bussis and Chittenden, 1970; Walberg and Thomas, 1971). Studies by Barth (1970), Bussis and Chittenden (1970), and Rathbone (1970) have identified ten characteristic themes of open education. A subsequent review (Walberg and Thomas, 1972) reduced this number to eight and provided strong empirical evidence that these themes distinguish open from traditional education. Themes most characteristic of open education included:

(a) The student has a degree of choice as to the direction of his learning;
(b) The extensive use of manipulative materials as an aid to learning;

(c) The flexible scheduling of learning periods;
(d) The provision of a great range and diversity of learning activities; and
(e) A high degree of pupil and teacher participation in the learning situation.

Featherstone (1971) observed that student choice of learning activities was a key characteristic of the OPEN environment. Students go from one activity to another as they choose; they work alone, in pairs or groups; different ages mix together, and a great deal of verbal interaction ensues. The organisation is flexible and classes do not follow a rigid timetable. "Not only is time allowed to vary for each student but so are the methods of instruction" (Gage, 1975, p.588). These same features would characterise an operational open environment in a Teachers College mathematics programme. Several writers (for example Henry, 1963; Holt, 1964; Jackson, 1968; and Silberman, 1970) gave an impetus to the open-education movement by their reported conceptions of life in the typical primary school classroom and criticisms of conventional teaching practices. In general, the majority of primary pupils have very uniform classroom experiences (Hughes, 1962; Perkins, 1964; Furst and Amidon, 1967). Descriptive studies have been used to develop normative data on teaching as it occurs in typical classrooms. Using category systems, investigators of classroom behaviour (Anderson, 1939; Flanders, 1960; Amidon and Hunter, 1967) have concluded that there is little difference in the interaction patterns that occur when teachers teach different subjects in elementary classrooms (Smith, 1971).

It is also likely that student teachers enter college with a particular conception of teaching based on their own direct experiences (Shaplin, 1962). It is quite natural for the novice teacher to imitate the most recently admired models either consciously or unconsciously because the range of recent experience does not include models who may be more appropriate for present conditions. Smith (1971) claims that there is little difference in the style of instruction as it occurs in many classrooms. It follows that it is likely that student teachers will enter college with fixed and reasonably uniform attitudes concerning the nature of the teaching process.

It is evident that open teaching does follow procedures which differ from those used in conventional teaching situations. Teachers who work in an open plan unit are required to interact closely by communication, planning, co-operating, and functioning as a professional team (New Zealand Education Department, 1976).

Different types of pre- and in-service training appear to be called for, if just to prepare teachers adequately for open plan education. Brunetti (1971), in a survey of open plan schools in 43 States of the U.S.A., reported that school principals highlighted teacher training needs of a specialised type. This need is reinforced by recommendations in the 1976 report on open plan education in New Zealand. A survey of 336 New Zealand primary school teachers practising open teaching found that almost 30 per cent of those teachers recommended practical open learning for student teachers within the structure of their college programme.

Open education includes a variety of instructional methods. The research evidence (Wasylyk and Kieren, 1971) suggests that a process of instruction which includes such a variety is more effective in the improvement of student attitude and mathematics achievement than is a process which consists only of a single method of instruction. This view is supported by the findings of Vance, 1969; Wilkinson, 1970 and Johnson, 1970.

Studies concerned with an evaluation of the effectiveness of open teaching (for example Wilson, Stuckey and Langevin, 1972; Wright, 1975) have tended to focus upon the primary classroom. This situation is not unexpected. Primary schools are staffed by general rather than specialist teachers. This situation appears to facilitate the process of open education. Teams of teachers can be readily organized to practise the process of open education over several different subject areas of the curriculum. Each teacher can assume responsibility for his area of interest and the one teaching team participates in the total open programme. It is more difficult for secondary and tertiary subject specialist teachers to contribute in curriculum areas outside their specialisation. Only three tertiary institutions in either Australia or New Zealand report the practice of open teaching as a means of instruction within their college curriculum. Barry and Connors (1974) report an open education programme for ninety third-year students at Alexander Mackie College, Sydney. Colvin (1976) and Ruhen (1976) report open education methods of instruction for students in mathematics education at Kelvin Grove College, Brisbane, and Churchlands College, Perth, respectively. No empirical findings have been reported concerning the effect of an open method of instruction upon the attitude of Teachers College students toward mathematics.

Evaluation : Issues and Problems

The evaluation of any method of instruction has unique purposes and problems. In general, evaluation is concerned with the systematic gathering of evidence regarding changes in student behaviour that accompany planned educational experiences (Harris, 1963). It has been stated (Hogben, 1974) that linear evaluation models, which allow for little more than the assessment of the extent to which detailed objectives are finally present as programme outcomes, are quite inadequate. Robert Stake (1967) draws attention to the importance of the evaluator searching for the presence of outcomes other than those intended. Scriven (1971) introduced the idea of 'goal free' evaluation and thereby gave the search for side effects of instruction a new prominence. Many studies concerned with programme evaluation investigate the decision aspect rather than the behavioural nature of the criterion (Cronbach, 1963; Wiley, 1970).

A number of studies evaluate the effectiveness of one method of instruction in comparison with some other method. Cronbach (1963) and Jackson (1967) argue vigorously against evaluations based upon programme comparison. Comparative studies are not only complex but often fail to observe two contingencies. The programmes may not only involve different methods of instruction but also a difference in objectives and there is the definite possibility of important side effects being overlooked. Scriven (1967, pp.51-52) opposes the view that evaluation must be non-comparative. "When we come to evaluate the curriculum, as opposed to merely describing its performance, then we inevitably confront the question of its superiority or inferiority to the competition". He goes on to say that the evaluation question asked should be "How good is the course?" rather than "How well does the course achieve its goals?" Thus any full and thorough evaluation of instructional methods must be both comparative and non-comparative.

Since open education involves goal emphases and methods of instruction that differ so markedly in many respects from traditional methods, any thorough-going evaluation cannot avoid the issue of goal evaluation. "However, to evaluate open education methods, solely in terms of the extent to which students in them achieve the special goals of those programmes, is not a valid alternative" (Hogben, 1974, p.235). The totality of outcomes flowing from open methods of instruction must be identified and evaluated. An educator faced with decisions affecting the adoption of curricula cannot rationally make such a decision unless empirical data are gathered which show how well a curriculum attains its own objectives, the objectives of competing curricula, and certain cross-curricular objectives (Glass, 1972).

Mathematics educators in Teachers Colleges are concerned ostensibly with minimising the discrepancy between intended and actual outcomes of the mathematics curriculum. For them, the main problem of an evaluative study is to establish the effects of the method of instruction on the students and to compare these effects with specified standards (Wiley, 1970). Comparative evaluations appear to be justified as a means of determining the effects of instruction upon goal attainment.

SELECTION OF CONTENT

A Phase in the Development of a Primary Teachers College Mathematics Curriculum

The literature suggests that the design of a mathematics curriculum for Primary Teachers College students is more than the determination of an instructional method. Several noted curriculum writers and theorists (Taba, 1962; Wheeler, 1967; Kerr, 1967; Hughes, 1973) have identified component elements of a theoretical curriculum model.

The first and most important phase of curriculum design (Taba, 1962; Wheeler, 1967; Kerr, 1967) is the formalisation of objectives. According to Hughes (1973), once objectives have been defined it is then possible to select appropriate content for the mathematics curriculum which encompasses facts, concepts, principles, relationships and techniques. The instructional phase, sometimes described as 'the organisation and integration of experiences and content', then follows these two earlier phases of curriculum design. If mathematics educators in Primary Teachers Colleges intend that students master the content of basic primary mathematics, it follows that the primary school mathematics curriculum will influence the selection of content for the Primary Teachers College mathematics curriculum.

Since the late 1950's there have been quite marked changes in the mathematics content of primary school programmes (Marks, Purdy and Kinney, 1970). There is a focus upon mathematical concepts, the structure of mathematics, and the nature of proof. There are refinements in the vocabulary, with attention given to the precision of expression, and the programme is mathematically rather than socially oriented (Grossnickle and Brueckner, 1965). Allendoerfer (1971) identifies two major content themes in current primary school mathematics programmes. One theme focuses upon the structure of the number system achieved by means of study of:

(i) logic, sets, and whole numbers;
(ii) fundamentals of the arithmetic of whole numbers;
(iii) algorithms for the arithmetic of whole numbers; and
(iv) extensions of the whole number system.

The second theme shows an emphasis upon spatial relations by means of an informal approach to geometry, which includes a study of

(i) geometric concepts and measurement; and
(ii) transformations and analysis.

Several authors of current primary mathematics programmes (for example Brumfield, Eicholz and Shanks, 1962; and Duncan, Capps, Dolciani, Quast and Zweng, 1972) have stressed the importance of set language and theory as a unifying construct particularly in the development of relations, functions, number theory, probability and transformation geometry.

The idea of student teachers all progressing through a fixed domain of mathematics content is questionable. Dienes (1964) states that the "real" intention of a mathematics curriculum is to encourage the search for patterns, structures, and relationships. Biggs (1966) recommends that students in training be given the opportunity to discover mathematical truths for themselves, and the truths, she says, should be concerned with the structure of the number system and spatial relations. Graham (1975) completed an analysis of all mathematics closely related to elementary school curricula and identified ten key topics:

1. Set theory.
2. Relations and functions.
3. Number systems.
4. Numeration systems.
5. Decimal fractions.
6. Ratio and proportion.
7. Percentage.
8. Number theory.
9. Probability and statistics.
10. Geometry.

It appears that mathematics educators concerned with the design of a mathematics curriculum will select content from key topics of the primary school mathematics programmes. The selection of learning experiences together with the organisation and integration of content and learning experiences will depend upon the specified objectives of the curriculum. The first step toward becoming an effective teacher of mathematics is mastery of the basic ideas. As student incompetence will not be uniformly confined to a specific area of mathematics content (Hughes, 1973), an appropriate organisation of content and learning experiences will offer each student a degree of choice as to the direction of his mathematics learning. It is undesirable for all students to progress at the same rate through a uniform domain of content (Dienes, 1964; Wheeler, 1967).

In this study it is intended to establish an OPEN mathematics curriculum which will provide the experimental group of students with alternatives. Each student will have some choice as to the method(s) of instruction experienced throughout the programme. In addition each student will choose to study one or several domains of mathematics content. The control group will not be provided with such alternatives. It is therefore intended that a CONVENTIONAL mathematics curriculum be established. This curriculum will attempt to provide the control students with a uniform set of learning experiences. At the conclusion of the two mathematics programmes it is intended to compare the mathematics attitude and mathematics comprehension of both student groups.

CHAPTER 3

PROCEDURES

INTRODUCTION

It has been suggested by several studies described previously in this investigation that:

(i) Changes in student behaviour can be influenced by a College mathematics curriculum. These changes are likely to be more significant if such a curriculum provides several methods of instruction (Kersh, 1965; Wasylyk and Kieren, 1971; Hall, 1974, p.58).

(ii) Teachers College programmes can change the attitude of students toward subject matter (Cox, 1960; Leton, 1961; Brim, 1966; McLeish, 1969),

(iii) The attitudes of older students toward subject matter are influenced to a lesser degree by such College programmes, than are the attitudes of younger students (McLeish, 1969).

(iv) There is a relationship between the mathematics attitude and mathematics comprehension of College students (Brim, 1966; Antonnen, 1967; Husen, 1967; Ryan, 1968).

These suggestions indicate that a College curriculum which does provide the student with some choice is likely to produce an improvement in both student attitude and student comprehension of mathematics. This improvement is likely to be greater than that which results from a curriculum without alternatives. The *choice* variables for this study are as follows:

(i) The domain of subject matter content which is to be learned.

(ii) The instructional strategy which a student is to experience.

(iii) (a) The time period which a student needs to complete the selected learning activities;

(b) The hours when a student chooses to participate in the learning activities.

The extent to which a student has a choice was the basis for the operational hypotheses of this study.

OPERATIONAL HYPOTHESES

(1) The mathematics attitude of College students immediately after a ten-week period of mathematics instruction will be more favourable than their attitude immediately before instruction.

(2) The mathematics attitude of College students after OPEN instruction will be more favourable than the attitude of students after conventional instruction.

(3) The mathematics comprehension of College students immediately after OPEN instruction will be greater than the comprehension of students immediately after conventional instruction.

(4) The mathematics attitude of direct-entry students immediately after instruction will be more favourable than the attitude of mature-age students immediately after instruction.

(5) The mathematics comprehension of direct-entry students immediately after instruction will be greater than the comprehension of mature-age students immediately after instruction.

(6) The mathematics attitude of female students immediately after instruction will be no different from the attitude of male students immediately after instruction.

(7) The mathematics comprehension of female students immediately after instruction will be no different to the comprehension of male students immediately after instruction.

THE SAMPLE POPULATION

The subjects of the sample population in this study were drawn from the 1977 intake of first-year students at Churchlands Teachers

College, Perth. All first-year students had been randomly assigned to twelve teaching sections immediately after the enrolment process. In this study the experimental and control groups each consisted of three teaching sections. The two groups made up a total of six teaching sections chosen at random from the twelve first-year sections.

Each student held either a direct-entry or mature-age studentship and during the enrolment week all subjects completed a mathematics ability test (Reid and Hughes, 1975, parts 6 and 7). Characteristics of the sample population are shown in Table 1.

TABLE 1

CHARACTERISTICS OF THE SAMPLE

Group	Section	Sex		Studentship		Mathematics Ability Test	
		No.of Males	No.of Females	Direct Entry	Mature Age	Mean Score	Variance
(OPEN) Experimental	1,2,3	17	46	37	26	32.65	27.19
Mean Age (years)	21.5	19.5	22.2	18.2	26.8		
(CONVENTIONAL) Control	4,5,6	22	41	31	32	32.76	40.06
Mean Age (years)	21.5	21.6	21.4	17.9	25.0		

DESIGN

The Solomon Four Group Design (Solomon, 1949) used in this study is shown in Table 2.

TABLE 2

THE SOLOMON FOUR GROUP DESIGN

Group	Selection	Pre-Test	Method	Post-Test	Condition
1	Random	0_1	X	0_2	Experimental
2	Random	0_3		0_4	Control
3	Random		X	0_5	Experimental
4	Random			0_6	Control

In this design the first two groups of subjects were formed in exactly the same way as in the Pre-test Post-test Control Group Design (Campbell and Stanley, 1963, pp.13-24). It is claimed that the Solomon design does overcome some of the generalizing difficulties encountered in the pre-test post-test design. It was selected for three reasons:

(i) To obtain the advantages of the Pre-test Post-test design.

(ii) To obtain a more powerful generalization than that which could result form the Pre-test Post-test Control Group Design.

(iii) To determine whether the pre-testing had an effect upon either student attitude or comprehension of mathematics.

The comparison of 'X' with 'no X' is an oversimplification. Campbell and Stanley (1963, p.20) state that, "The comparison is actually with the specific activities of the control group which have filled the time period corresponding to that in which the experimental group receives the X". In this study:

(i) X represents the OPEN method of mathematics instruction.

(ii) No X represents the CONVENTIONAL method of mathematics instruction.

(iii) 0_1 is equivalent to 0_3 and each represents a pre-test observation.

(iv) 0_2 is equivalent to 0_4, 0_5, and 0_6 and each represents a post-test observation.

The application of the Solomon Design to this study is shown in Table 3.

TABLE 3

APPLICATION OF THE SOLOMON DESIGN

Group	Student Sections	Pre-Test	Method of Instruction	Post-Test
1	Half of 1,2,3	none	OPEN	02
2	Half of 1,2,3	01	OPEN	05
3	Half of 4,5,6	none	CONVENTIONAL	06
4	Half of 4,5,6	03	CONVENTIONAL	04

This investigation was concerned primarily with an evaluation of instructional methods. Evaluation, in this sense, is defined by Wiley (1970, p.261) as the 'collection and use of information concerning changes in pupil behaviour to make decisions about an educational programme'.

The main problem of evaluation was to determine the effects of mathematics instruction upon the mathematics attitude and comprehension of first-year College students. Before this task was attempted it was necessary to define explicitly the research variables, shown in Table 4.

TABLE 4

IDENTIFICATION OF RESEARCH VARIABLES

Independent Variables	Experimental Variables	Dependent Variables	Covariates
Sex	Method of mathematics instruction	1. Attitude toward mathematics	1. Attitude toward mathematics (Pre-test)
		2. Mathematics comprehension	2. Mathematics ability

DEFINITION OF RESEARCH VARIABLES

Studentship

Two types of studentship are defined in this study. A direct-entry studentship is the entry award made to those students who enrol at Teachers College direct from secondary school. A mature-age studentship is that award made to students who do not enrol direct from secondary school and are at least nineteen years of age at the time of enrolment.

Attitude Toward Mathematics

Definition: Student attitude toward mathematics is determined by a score calculated from an individual's response to twenty-eight mathematical situations. These situations are put to each student by means of a questionnaire (see Appendix A). Questionnaire items are selected on the basis of their conformity with the Rasch Multiplicative Binomial Response Model (Andrich, 1976). Each mathematical situation is related to either the teaching of primary school mathematics or the content domains of the primary school curriculum. Four Likert type response categories are provided with each item and these give each student the opportunity of expressing the intensity of feeling aroused by any particular item.

The linear continuum model of the attitude construct (Oppenheim, 1966, p.107) is used in this study. In this model, high scorers are located nearer one end of the continuum than are relatively low scorers. The relatively high scorers are described as positive and are expected to exhibit the following behaviours in mathematical situations:

(i) An approach rather than an avoidance of mathematics situations.

(ii) An enjoyment of rather than a dislike for mathematics situations.

(iii) A confidence in rather than a hesitancy toward mathematics situations.

(iv) An interest rather than a disinterest in mathematics.

(v) A pursuance of mathematics in preference to other subject areas.

(vi) An endeavour to interest others in mathematics.

THE MEASUREMENT SCALE

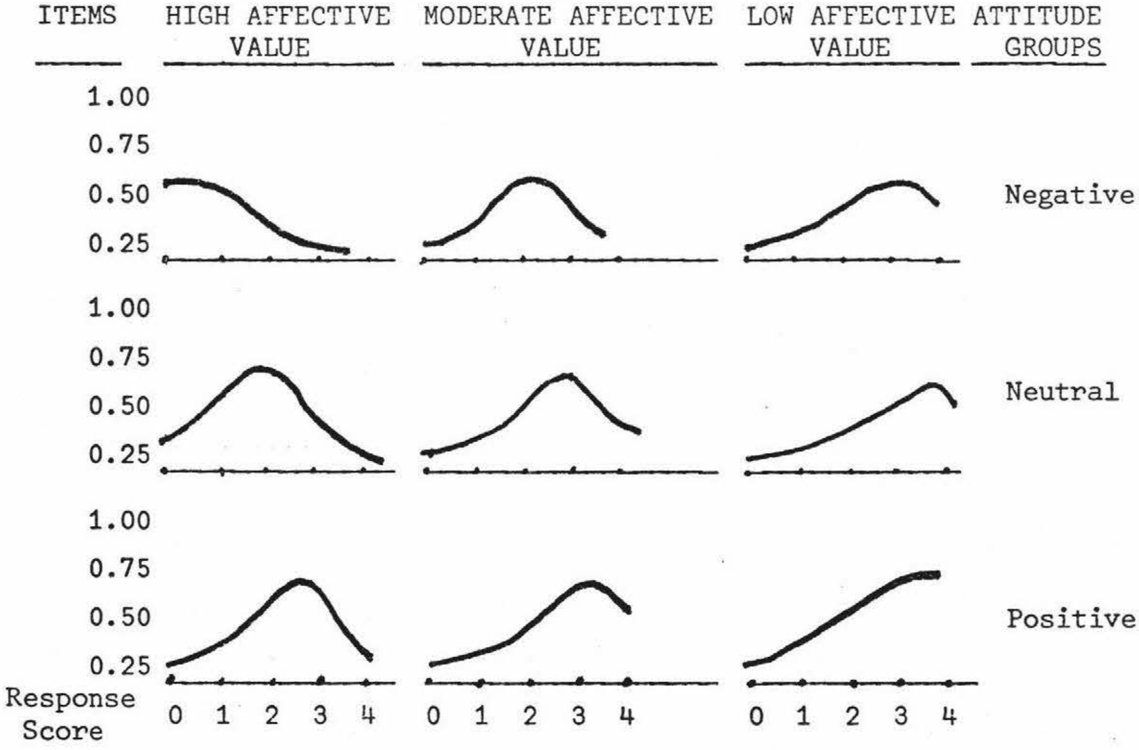
Theoretical Basis

The attitude scale used in this study is based upon the Rasch Multiplicative Binomial Response Model. In the past, the Rasch simple logistic model (Rasch, 1960) has been used to analyse responses to attitude questionnaires (for example Kuncel and Fiske, 1974; Thomson and Parkin, 1975) but its primary function has been to analyse the scores of a group of persons who responded dichotomously to a set of achievement items. When subject responses are of a dichotomous nature they are scored accordingly as either 0 or 1. A person's response to an attitude item is therefore restricted by the dichotomous nature of the alternatives. A recent development by Andrich (1976) generalises the simple logistic model to the case where the response pattern to each item is binomial. A critical feature of both the simple logistic and the multiplicative binomial models is that the parameters of two classes of agents can be estimated independently of each other. The attitude-of-subject parameters are estimated independently of the unknown item-affectivity parameters. Conversely, the item-affectivity parameters are estimated independently of the attitude-of-subject parameters.

Andrich (1976, p.3) states two reasons why it is possible to construct attitude items scored in the Likert tradition that conform to the multiplicative binomial model.

> ...an intuitive inference regarding variations in the patterns of responses when people of different attitude respond to items of different affective value, accords with this mode. For example: Assume that a specific item has an affective value which places it in the middle of some attitude range of interest. The responses to that item are scored as zero, one, two, three, or four. A score of four indicates a more positive attitude than does any other score. It is then expected that the majority of subjects in the lowest attitude group would tend to score 0 or 1, that the majority of those in the middle attitude group would tend to score 2, while those in the high attitude group would tend to score 3 or 4. Figure 3 illustrates these expectations. A similar response pattern may be expected if a group of subjects having the same attitude respond to items ranging from high to low affective values. This pattern is illustrated in the rows of Figure 3.

FIGURE 3 : Intuitive inference regarding the relative response patterns of subjects with different attitudes to items of different affectivities.



The relevance of the multiplicative binomial model is that when the response scores and affective values are varied as in the previous examples, the theoretical probabilities illustrate the same patterns as in Figure 3" (Andrich, 1976, p.5)

In the past it has been conventional to simply sum scores over items to obtain a measure of a subject's attitude. This simple additive procedure is also a feature of the multiplicative binomial model. The sum of scores over all the items is a sufficient statistic for the estimation of a subject's attitude. Conversely, if attitude data which are collected in the Likert format do conform to the model, there is an established and rational justification for simply adding the scores of a subject over the items.

Development

It was necessary to develop a mathematics-attitude scale for the first year students used in this study. Previous studies have investigated the mathematics-attitude of College students (Aiken and Dreger, 1961; Dutton, 1962; Antonnen, 1968; McCallon and Brown, 1971) but these studies use either the Thurstone or Likert type scales. The disadvantages of using only the Likert or Thurstone techniques compared with the Rasch process have been described in this investigation. A further disadvantage, however, is that some attitude scales contain inappropriate items for first year College students in 1977. These items refer to domains of mathematics content which are not included in the mathematics curricula of Teachers Colleges in either Western Australia or New Zealand. The development of an appropriate attitude scale is dependent then upon the successful construction of thirty valid items which conform with the Rasch Multiplicative Binomial Response Model. For this purpose two pilot studies were carried out during 1975 and 1976.

In March 1975 one hundred and eight randomly selected first year students at Churchlands Teachers College responded to a mathematics attitude questionnaire. The questionnaire consisted of thirty items selected from three sources:

(i) The National Longitudinal study of Mathematics Attitudes (Wilson, Cahen and Begle, 1968a, 1968b).

(ii) Attitude Questionnaire (Aiken and Dreger, 1961).

(iii) Mathematics Attitude Questionnaire (Dutton, 1962).

These items were then adapted for Primary Teachers College students. MULTBINI (Jennings, 1976), a computer program which uses the Rasch technique, processed their response patterns to this questionnaire. The same program also determines the degree to which each item fits with the Multiplicative Binomial Model (Andrich, 1976, p.19). First, the items are tested collectively for joint fit with the model. Second, each item is tested for individual fit with the model (Andrich, 1976, p.22).

Students were requested to make an honest response to each item and to help reduce the influence of staff expectations, each questionnaire was returned anonymously. It was found necessary to eliminate from the questionnaire two items which did not conform with the model. Later discussions with the students showed that four other items caused some confusion and were subsequently replaced.

This first pilot study required each student to make a response in one of five categories. An undecided category was provided. There is evidence, however, that this middle category ('don't know' or 'undecided') should be left out. Punch (1972) reports that very few students use this category. If they do, the returns give the middle category a very depressed value in relation to the others. In addition, the undecided response is not utilised when subjects are required to simply agree or disagree with items (Bock and Jones, 1968). It follows that there is no logical reason for it to be included when the response categories are extended. There is also a problem with the scoring of this category when items are scaled according to affectivity (Punch, 1972). For these reasons, the middle category was removed from the response set available in the second pilot study.

The second pilot study was carried out in March 1976. Ninety-six randomly selected first year primary students at Churchlands Teachers College responded to a revised set of twenty-eight items. A copy of this questionnaire is shown in Appendix A. Only four response categories were provided and the scoring of items in negative form was reversed.

The scoring of the attitude questionnaire has been described in this study but it is repeated that an item score of 3 does indicate a more positive expression of mathematics attitude than does any lesser score for the same item.

In order to determine the joint fit of items with the model the original sample of subjects was divided at the median attitude score into two mutually exclusive groups. A parameter estimate of each item is then calculated from the response patterns made by each of the two groups. Chi-square is used to test the null hypothesis that there is no significant difference between the two sets of parameter estimates.

In this study the MULTBINI computer program calculated chi-square at 61.0457, d.f. = 5.4, $p < 0.05$. This result indicates that the null hypothesis can be accepted. It follows that the twenty-eight items collectively fit the multiplicative binomial response model.

The Rasch process also determines the attitude affectivity of each item along a response continuum (Andrich, 1976, p.36). It is also possible to distribute the attitude scores of subjects along the same continuum (Andrich, 1976, p.34). The item affectivity and subject attitude distributions for the students of 1976 are shown in Figure 4.

It follows from Figure 4 that one half of the students tend to endorse positively those items located to the left of item 8. It is expected that a student who does endorse positively item 26, but does not so endorse item 21, will obtain an attitude score of 61. Items endorsed positively by all students are located on the continuum to the left of item 17.

A list of the items, worded in positive form and arranged according to their affectivity, is shown in Appendix B. The least affective item is shown first and is that item endorsed positively by a student with even a relatively negative attitude toward mathematics. Only subjects with a very positive attitude toward mathematics are likely to endorse the most affective item (Andrich, 1976, p.37). A numeric score is obtained from the response pattern made to the 28 items and is then used as the measure of student attitude toward mathematics.

In March 1977, forty subjects were selected randomly from the first year group of students who were not going to take part in either of the mathematics programmes. These subjects completed two mathematics attitude questionnaires. The twenty-eight item attitude scale developed for this study and the twenty-one item E and V scale developed by Aiken in 1974 were listed as two separate sections in a test booklet. Each of the two sections was first attempted by one half of the selected students. The total scores on the E and V scale

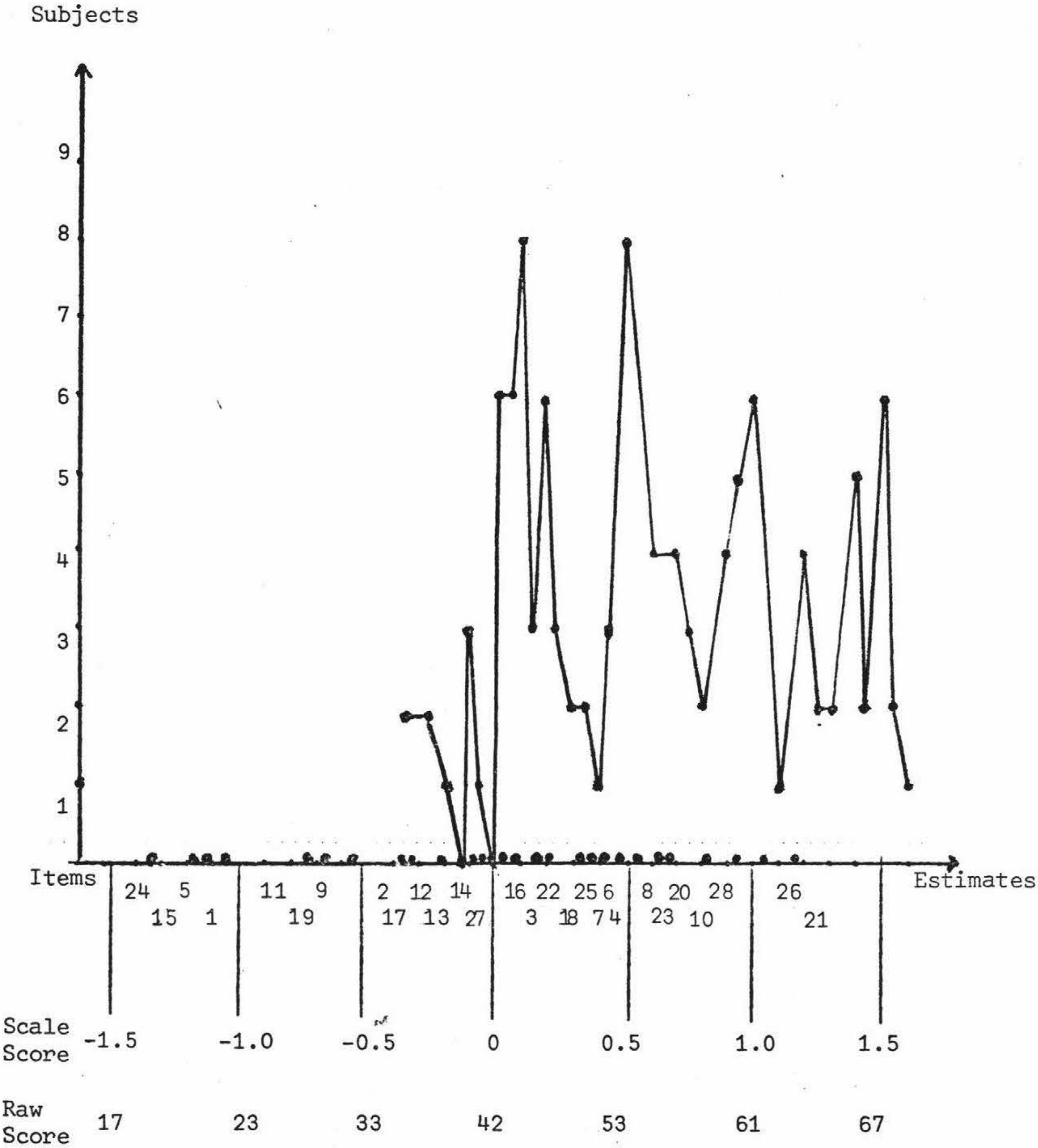


Figure 4 : The item affectivity and subject-attitude estimates. Frequency distributions for the 1976 pilot study.

(Aiken, 1974) were then correlated with the total scores on the attitude scale developed for this study. A Pearson product moment correlation, r = 0.72, was obtained. Mean scores of 56.57 (s = 13.34) and 74.53 (s = 17.36) were calculated for the Aiken and Research scales respectively. The scattergram of scores for both attitude scales is shown in Figure 5.

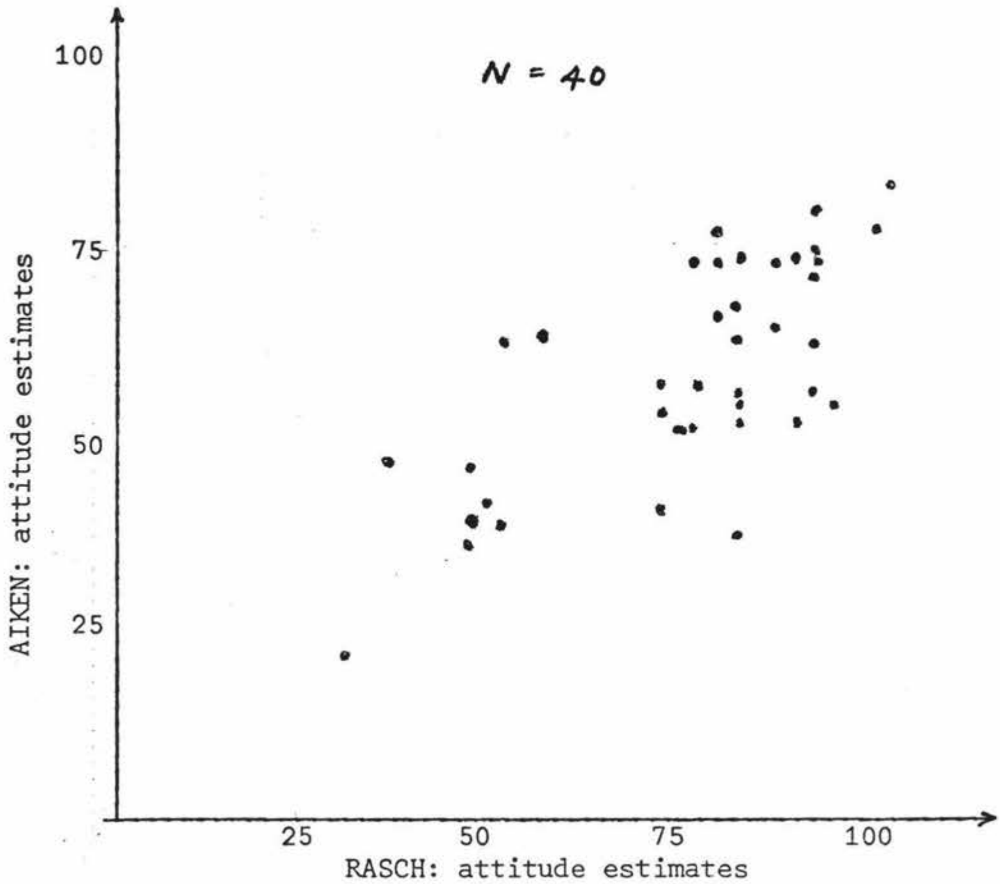


Figure 5 : Scattergram of scores on the Aiken and Research attitude scales.

<u>Mathematics Ability</u>

In this study it is necessary to distinguish between mathematics ability and mathematics comprehension. Mathematics ability is the numeric score obtained by a student in answer to fifty questions from parts 6 and 7 of the Progressive Achievement Test in Mathematics (Reid and Hughes, 1975). This test was developed by the New Zealand Council for Educational Research and is of the omnibus type. It emphasizes power rather than speed and consists of fifty multiple-choice questions, each with either four or five options. The items are arranged in two cycles roughly in order of difficulty. The students attempt blocks of Recall, Computation, Understanding and Application items in each half of the test. The Progressive Achievement Test was selected for the following reasons:

(i) The standardised PAT mathematics test is carefully constructed by a team of expert personnel and according to the principles of test design (Myer, 1967). Although the multilevel tests (eight years of age to fifteen years of age) cover specific content areas of New Zealand primary school mathematics curriculum, there is a very close match with the content areas of the Western Australian primary school curriculum.

(ii) An objective of the Teachers College mathematics curriculum states that students should master the mathematics content of the primary school curriculum. An instrument which evaluates the mathematics ability of upper primary pupils was considered appropriate also to evaluate the mathematics ability of Primary Teachers College students.

(iii) It was decided to use parts 6 and 7 of the Progressive Achievement Test as these sections contained areas of mathematics content from the upper grade levels.

(iv) There is no comparable test produced in Western Australia.

(v) In Western Australia there is no standardized test which measures the mathematics ability of Primary Teachers College students.

(vi) There is a high correlation between the Progressive Achievement Test and other tests of mathematics ability (Reid and Hughes, 1975).

The scores of mathematics ability are to be used as a covariate in the statistical comparison between the two sample groups.

Mathematics Comprehension

Mathematics comprehension is the score obtained by each student in response to twenty-five mathematics questions. A particular domain of mathematics content was selected for the OPEN and CONVENTIONAL mathematics curricula. The twenty-five questions are all within the domain of content specified for this study (number and numeration) and are selected from the following sources:

(i) The National Longitudinal Study of Mathematics Abilities (Wilson, Cahen and Begle, 1968a, 1968b).

(ii) Mathematics Item Bank, Level 6 (Department of Education, New Zealand, 1973).

The mathematics comprehension test is shown in Appendix C. The pre-test and the post-test scores will be compared to help determine the effects of mathematics instruction with College students.

The Method of Instruction

Two methods of mathematics instruction were used in this study with two similar groups of students. The objectives were the same for each group and stated that after instruction there will be an improvement in:

(i) Student attitude toward mathematics.

(ii) Student comprehension of mathematics.

A mathematics learning centre (Thomas, 1975) was developed for the ninety students in teaching sections 1, 2 and 3. The mathematics activities in this centre were organized into three content areas, as shown in Table 8, and were structured by the method of component analysis (Resnick, 1975) into a curriculum sequence. The experimental group of students were given a choice in each of the following phases of the OPEN mathematics curriculum.

(i) Mathematics Content: Each student chose one or more content areas in the learning centre depending upon individual needs or interest.

(ii) Methods of Instruction: Four methods of instruction were available to each student within each of the choice content areas. A student chose one or several of these methods. The four methods are listed as follows:

(a) Programmed instruction (P)
(b) Discovery instruction (D)
(c) Lecture-Tutorial instruction (L)
(d) Media assisted instruction (M).

(iii) Time Schedule: The students were not expected to follow identical time schedules in the open curriculum. Each student chose (a) which class periods they would attend, and (b) the amount of time which they would require to complete their chosen areas of content.

There was considerable emphasis upon the student's use of manipulative materials in the open curriculum. The activities did require that sometimes the students worked alone, sometimes in pairs and sometimes in small groups. An introductory set of activities had been developed to familiarise the experimental group of students with the three content domains of the learning centre. The introductory activities were attempted in the first week of the open programme before areas of content were elected for special study by the students.

The experimental group of students could meet with staff individually once each week to discuss content and procedural problems. These meetings were called consultations and each student was expected to attend at least five such meetings throughout the open programme. Some students chose to meet with a staff member during scheduled class time but other students arranged a private meeting outside timetabled hours.

Media services were available at the College Audio-Visual Centre. The students who elected media-assisted instruction could use the services of this centre at any time.

The three content areas of the mathematics learning centre together with associated materials and activity booklets, were established in separate locations of the open space. A curriculum sequence guide was available for each area of content and these are shown in Appendix E. The purposes and organisational procedures of the open curriculum were discussed with the students at the beginning of the programme. The role of mathematics staff in the open programme was advisory and supportive rather than expository and directing.

A lecture-tutorial method of instruction was used with the second group of students from teaching sections 4, 5 and 6. In this method the three content areas of the conventional mathematics curriculum were organised into nine lecture topics. This organisation is shown in Table 5.

TABLE 5

CONVENTIONAL CURRICULUM : ORGANISATION OF CONTENT

Content Area		Lecture Topics	Week
Number Sets	o	The Shape of Numbers	1
	o	Primes, Composites, Factors, and Multiples	2
	o	Number Patterns	3
Numeration	o	Decimal System	4
	o	Other Systems	5
	o	Characteristics of Numeration Systems	6
Number Systems	o	Modulo Arithmetic	7
	o	Finite Systems	8
	o	Properties of Systems	9

The content of each topic was presented in an expository style to each of the three teaching sections. A worksheet of related problems was issued to each student at the end of the lecture. Two members of the mathematics staff were available to assist the students with these worksheet problems at the weekly tutorial session. This method of instruction made no special provision for different abilities in mathematics. All students experienced the same set of learning experiences at the same time and at the same rate. The organisation used to present both the conventional and open programmes is shown in Table 6.

TABLE 6

ORGANISATION TO PRESENT THE CONVENTIONAL AND OPEN PROGRAMMES

Condition	Teaching Section	Timetable Period				Staff Responsible
Experimental (OPEN)	1	Monday	am	Thursday	pm	A & B
	2	Tuesday	am	Friday	pm	C & D
	3	Friday	am	Tuesday	pm	E & F
Control (CONVENTIONAL)	4	Monday	am	Thursday	pm	E & F
	5	Tuesday	am	Friday	pm	A & B
	6	Friday	am	Tuesday	pm	C & D

MATERIALS

The Mathematics Learning Centre

The mathematics learning centre consisted of three related sets of learning activities. Each set of activities was designed to improve the students' understanding of concepts and principles within one of the specific areas of mathematics content. The three areas of mathematics content selected for the learning centre are as follows:

(i) Numeration : place value and number bases.

(ii) Number systems.

(iii) Number sets.

In addition, each set of activities provided the experimental group of students with the following alternate styles of instruction: discovery instruction, programmed instruction, lecture-tutorial instruction and media-assisted instruction. The use of manipulative materials was required in almost all of the activities.

A separate instructional booklet (Ruhen, 1977a, 1977b, 1977c) for each area of content contained procedural information. This information directed the student to particular learning experiences after a method of instruction had been chosen. Students who chose the media assisted method of instruction were directed to certain filmstrips, films, cassette-tapes, slides and television productions. A similar provision was made for the students who chose the lecture-tutorial method. The same booklets also contained the programmed and discovery learning activities. The content areas of the mathematics learning centre together with relevant materials and instructional aids were located in three separate areas of the open learning space. The structure of the mathematics learning centre, associated materials and relevant sources are described in Appendix D.

Open Learning Space

The students in the open mathematics programme used a large, carpeted area for their learning experiences. There was no set furniture arrangement in the open space. The students organized their own learning environment. Diverse furniture patterns occurred and the carpeted floor, moveable screens, abundant storage and mobile trolleys facilitated the environmental transformations. A plan of the open space is shown in Figure 6.

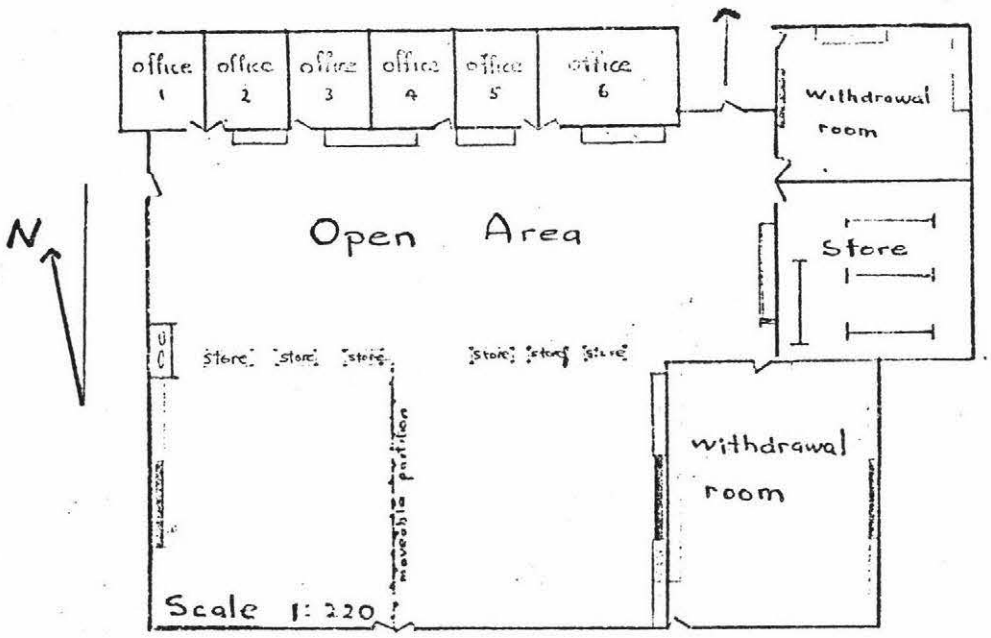


Figure 6 : Plan of open learning space.

The Conventional Programme

The conventional mathematics programme was allocated two one-hour periods for each of the ten weeks. Three areas of mathematics content were organised into nine sequential lecture topics and each was presented to the students in the first of the one-hour periods each week. A tutorial workshop was held in the second hour. Three pairs of staff were responsible for the presentation of the conventional programme. Each pair presented the nine lectures and tutorials to one of the three teaching sections in the control group. The structure of this programme with related references is described in Appendix F.

The Conventional Learning Environment

The conventional mathematics programme was presented in an architectural space similar to that used in the open programme. The furniture was uniformly arranged and maintained in a rectangular matrix of rows and columns. Students were seated individually throughout the lecture and tutorial sessions.

PROCEDURES

Staff Preparation

A particular set of experiences prepared staff for this experimental study. In 1975 and 1976 all mathematics staff taught in the conventional programme. As the same staff were to be used in the open curriculum it was necessary that they have some conception of the open education construct. The experiences designed to help with such a conception included:

(i) Staff meetings to discuss the learning centre as an organisation for instruction. Staff also discussed the method of component analysis (Resnick, 1975) which was to structure the learning centre activities into a curriculum sequence.

(ii) A subject-type learning centre (Thomas, 1975) was established as a model. It was also evaluated by staff.

(iii) A second year mathematics elective was used in 1975 and again in 1976 as a pilot study for the open curriculum. An open method of instruction which used a learning centre organisation was a feature in this elective. All staff who were to take part in the open curriculum were active instructors in this elective.

(iv) Films[1] and articles[2] on open education were reviewed with colleagues from the Education Department.

(v) Open methods of mathematics instruction were observed in several primary schools.

(vi) Staff identified the "presage and process variables" (Dunkin and Biddle, 1974, pp.39-44) which characterised their own

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[1]Films: 'Open Classroom', London, Open University, 1972; 'Open Classroom', BBC Walton, Open University, 1971; 'The Open Classroom', Torrance, California, Sherwin P. Rubin.

[2]Articles: Thomas, J., Learning Centre : Opening up the Classroom, Holbrook Press, 1975; Gray, W.A., Preparing Teachers for Open Space Schools, Fac.Ed., Uni B.Colombia, 1975; King, L, The Open Classroom : Learning to Choose and Choosing to Learn, Churchlands T.C. Press, 1975.

conception of open instruction. The presage and process variables of the open curriculum are described in Appendix G.

(vii) Staff first developed and then evaluated the mathematics learning centre used in the open curriculum. The evaluation was based upon the following considerations:

(a) Is the mathematics content appropriate for first-year College students?

(b) Is the content within the areas specified for this study?

(c) Are the presage characteristics (Dunkin and Biddle, 1974) of open instruction present in the organisational framework?

(d) Are the process characteristics of open instruction likely to occur during the instructional phase of the open curriculum?

Assignment of Staff to Groups

The six members of staff were paired randomly to form three instructional teams. Each team was then assigned randomly to one teaching section from (a) the experimental group, and (b) the control group. It follows that each member of staff took part in both instructional programmes. Table 6 illustrates the allocation of staff to the different groups of students.

Although all teaching sections were formally timetabled for mathematics instruction, it was possible to vary the scheduled pattern with sections from the experimental group. If alternative times for mathematics instruction were required, a mutually acceptable arrangement was made between the students and staff. The simultaneous scheduling of one section from each condition made it possible for experimental students to take part in the conventional method of mathematics instruction.

Data Collection

Before the open and conventional mathematics programmes began it was necessary to collect the following information for the analytical purposes of this study:

(i) The mathematics ability of each student in the sample.

(ii) The mathematics attitude and mathematics comprehension of half of the students in each of the two groups within the sample.

The mathematics ability of each student was determined from each score on the fifty items of Parts 6 and 7 from the Progressive Achievement Test in Mathematics (Reid and Hughes, 1975). The selection of these problems and the scoring procedures have already been described in this study. During enrolment week all first-year students completed this ability test and procedures for its administration were obtained from the PAT Manual (Reid and Hughes, 1975, p.9). The tests were marked by one member of staff and the score obtained by a student represented his or her mathematics ability. A pretest to determine mathematics attitude and mathematics comprehension was given two weeks later.

The mathematics attitude and comprehension pretest was given to one half of the students in each of the two groups within the sample. The pretested students were selected randomly and the test was given immediately before mathematics instruction began. The purpose of the pretest was to obtain data from which the mathematics attitude and the mathematics comprehension of both student groups was calculated. Student attitude toward mathematics was determined from the response made to a twenty-eight item questionnaire. The development and scoring of this questionnaire has been described previously in this investigation. The students' comprehension of mathematics was determined from their response to twenty-five mathematics problems. The selection and scoring of these problems has also been described in this study. The attitude items and comprehension problems were each listed as a separate section in the test booklet. While one half of the pretested students completed the attitude section of the booklet, the other half completed the comprehension section. Two rooms were scheduled simultaneously for the presting and at the same time those students not required to complete the pretest were directed to another room for administrative purposes. The pretest organisation is set out in Table 7.

Before the students began their first section of test items the following procedures were observed:

(i) Students were directed to read the introductory information as it appeared in the test booklet (Reid and Hughes, 1975, p.9).

TABLE 7

PRETEST ORGANISATION

Condition	Sub-Group	Student Sections	Selection	Pretest	Room
Experimental (OPEN)	X1	One quarter of sections 1,2,3	R	Part A first	P
		One quarter of sections 1,2,3	R	Part B first	Q
	X2	Half of sections 1,2,3	R	none	T
Control (CONVENTIONAL)	C1	One quarter of sections 4,5,6	R	Part A first	P
		One quarter of sections 4,5,6	R	Part B first	Q
	C2	Half of sections 4,5,6	R	none	T

(ii) Staff supervisors directed the attention of students to the time period allocated for each section of the test.

(a) Section A (Attitude items) - 30 minutes.
Thirty minutes was more than sufficient for every student to complete Section A. (In 1975 the slowest student took 25 minutes to complete the attitude section of the pretest).

(b) Section B (Mathematics Comprehension) - 45 minutes.

(iii) Students were directed to record their sex, studentship and identification number in the spaces provided.

(iv) Students were directed to the illustrative examples.

(v) The procedures (i)-(iv) were repeated for the second section of test items.

(vi) A computer programme MULTBINI (Jennings, 1976) processed the attitude responses. MULTBINI used Rasch procedures and provided a separate attitude score for each student. The comprehension scores were calculated by a member of staff.

A post-test was necessary to obtain the mathematics attitude and mathematics comprehension of each student in the sample immediately after the period of mathematics instruction. All students in the sample responded to the same set of attitude and comprehension items as had been given in the pretest. The post-test procedures were otherwise identical with those set for the pretest.

STATISTICS

This study is concerned with the effects of mathematics instruction upon attitude and comprehension of mathematics in a teachers college setting. The first and third hypotheses stated that there will be an improvement in the attitude and comprehension of mathematics by students after a period of instruction. Two analyses of variance with repeated measures are to be used for the purpose of determining whether such an improvement has occurred. The pretest attitude and comprehension scores will be compared with the post-test attitude and comprehension scores. It is expected that student responses to the pretests may show relatively large variability. It is thought possible that much of this variability could be due to differences between the subjects which exist prior to the experiment. The repeated measures design has been selected because "...it separates the between people variability from that due to treatment effects and experimental error" (Winer, 1962, p.105). As a result, the sensitivity of this experiment could be increased. Only the pretested subjects provide the data for this repeated measures analysis. Each of these subjects was pretested and post-tested to determine the attitude held toward mathematics before and after instruction. Similarly, mathematical comprehension before and after instruction was determined. The relevant variables for the two analyses of variance with repeated measures are shown in Table 8.

It was next decided to consider whether the pretesting had a significant effect upon either the post-test attitude scores or the post-test comprehension scores. Only one half of the students in the sample were given the attitude and comprehension pretest. It was planned to compare the post-test scores of attitude and comprehension from the pretested students with similar post-test scores from the students who were not pretested. Two one-way analyses of variance were used for this purpose. The relevant variables are shown in Table 9.

TABLE 8

ANALYSIS OF VARIANCE WITH REPEATED MEASURES

	Mathematics Attitude Treatment		
	Subjects	Treatment 1	Treatment 2
Analysis 1	Each pretested person in sample	Pretest scores of attitude	Post-test scores of attitude
	Mathematics Comprehension Treatment		
	Subjects	Treatment 1	Treatment 2
Analysis 2	Each pretested person in sample	Pretest scores of comprehension	Post-test scores of comprehension

TABLE 9

ANALYSIS OF VARIANCE

Analysis 1	Group	Attitude
	Pretested	Post-test attitude
	Unpretested	Post-test attitude
Analysis 2	Group	Comprehension
	Pretested	Post-test comprehension
	Unpretested	Post-test comprehension

From the row means in the first analysis the main effects of pretesting upon mathematics attitude can be estimated. Similarly, the main effects of pretesting upon mathematics comprehension can be estimated from the second analysis.

Hypotheses 2-7 are concerned with the relative effects of two methods of instruction upon the two criterion variables of mathematics attitude and mathematics comprehension with different student groups. It has already been stated that after an open method of mathematics instruction student attitude and comprehension scores will be significantly higher than if they are to receive a similar period of conventional instruction. No significant difference in the attitude and comprehension scores was expected between male and female students.

A significant difference was expected, however, between the mature-age and direct-entry students. Two factorial analyses of covariance were used to examine these major hypotheses. Each analysis examined the relative effects of the two methods of mathematics instruction upon one of the criterion variables with different student groups. The criterion variable of the first analysis of covariance is the post-test attitude toward mathematics. The criterion variable of the second analysis is the post-test comprehension of mathematics. The relevant variables and covariates are shown in Table 10.

TABLE 10

ANALYSIS OF COVARIANCE : RELEVANT VARIABLES

	Criterion Variable	Independent Variables	Covariate
Analysis 1	Attitude toward mathematics (post-test)	Sex. Studentship. Method of instruction.	Attitude toward mathematics (pretest)
Analysis 2	Mathematics comprehension (post-test)	Sex. Studentship. Method of instruction.	Mathematics ability

The analysis of covariance is a statistical method which controls variability due to experimental error. "This technique greatly increases the sensitivity of an experiment" (Davies, 1972, p.154).

It was considered that some of the differences in the post-test scores of mathematics attitude may be accounted for by differences in the mathematics attitude of students before instruction commenced. For this reason the pretest attitude scores are to be used as covariates in the first analysis. Similarly, the differences in post-test scores of mathematics comprehension may be accounted for by differences in the mathematics ability of students before instruction began. For this reason the mathematics ability scores are to be used as covariates in the second analysis. These assumptions will be checked by determining the correlations between the covariates and criterion variables before the analysis is undertaken.

CHAPTER 4

RESULTS

EFFECT OF INSTRUCTION

A. Mathematics Comprehension

After students have experienced a period of mathematics instruction it appears reasonable to expect an increase in their comprehension scores. Although two methods of instruction were used in this study, it was decided to first find out if there had been any change in student comprehension irrespective of the method of instruction. Comprehension scores were obtained before and after instruction from 64 subjects in both instructional groups. A single factor, repeated measurements analysis of variance (Winer, 1962, p.110) was used to determine the effect of instruction, irrespective of method, upon the comprehension scores obtained after the period of instruction. The results show a very significant difference between the comprehension scores obtained before and after instruction.

An inspection of the mean scores shows that the post-instruction scores are higher than the pre-instruction scores. A summary of the results of this single factor analysis of variance with repeated measures is shown in Table 11.

TABLE 11

A : ANALYSIS OF VARIANCE WITH REPEATED MEASURES : MATHEMATICS COMPREHENSION

Source	Sum of Squares	d.f.	Mean Square	F
Between subjects	1700	63	26.98	
Within subjects	1134	64	17.72	
Instruction	805	1	805	154.21 ($p<0.001$)
Residual	329	63	5.22	
TOTAL	2834	127		

TABLE 11 (cont.)

B : CELL MEANS : MATHEMATICS COMPREHENSION

Comprehension Score Before		Comprehension Score After	
mean $\bar{x}$ =	12.09	mean $\bar{x}$ =	17.33
S.D. =	4.08	S.D. =	3.73

Correlation coefficient $r = 0.62$

$(N = 64)$

The null hypothesis tested was H_o : Comprehension before instruction is no different than comprehension after instruction. The null hypothesis of equal comprehension means must be rejected on the basis of these results. It was concluded that the mathematics comprehension of first year College students is significantly higher after a period of mathematics instruction compared with their comprehension immediately before instruction ($F = 154.21$; $df = 1,63$; $p < 0.001$).

B. Student Attitude Toward Mathematics

Although it may appear reasonable to expect student attitudes toward mathematics to be more favourable after instruction, this outcome is less certain than the improvement in comprehension. In this study it was decided to find out if student attitudes toward mathematics had changed after instruction. Attitude scores were obtained before and after mathematics instruction from all the pre-tested students in both instruction groups ($N = 67$). A single factor, repeated measurements analysis of variance (Winer, 1972, p.110) was used to determine the effect of instruction, irrespective of method, upon the student attitude scores obtained after instruction. The analysis found a very significant ($p < 0.001$) difference between the attitude scores before and after instruction. An analysis of the pre-treatment and post-treatment means show that the scores obtained after instruction are higher than those obtained before instruction.

A summary of the results of the single factor analysis of variance with repeated measures is shown in Table 12.

TABLE 12

A : ANALYSIS OF VARIANCE OF MATHEMATICS ATTITUDE WITH REPEATED MEASURES : TESTING BEFORE AND AFTER INSTRUCTION

Source	Sum of Squares	d.f.	Mean Square	F
Between subjects	13338	66	202.09	
Within subjects	2780	67	41.5	
Instruction	890	1	890	31.22 ($p<0.001$)
Residual	1887	66	28.6	
TOTAL	16118	133		

B : CELL MEANS : MATHEMATICS ATTITUDE BEFORE AND AFTER INSTRUCTION

Attitude Score (Pretest)	Attitude Score (Posttest)
mean $\bar{x}$ = 51.81	mean $\bar{x}$ = 56.97
S.D. = 11.41	S.D. = 10.26

Correlation coefficient $r = 0.75$

($N = 67$)

The null hypothesis tested was H_1 : Attitude before instruction is no different from attitude after instruction. The null hypothesis of equal attitude means must be rejected on the basis of these results. It was concluded that attitude towards mathematics of College students immediately after a ten-week period of mathematics instruction is significantly more favourable than their attitude immediately before instruction ($F = 31.22$; d.f. = 1,66; $p < 0.001$).

TEACHING METHOD X TESTING

A. Mathematics Attitude

It is possible that taking a test for a second time can influence student performance. It is also possible that a comparison between the effects of two methods of instruction will show one of the methods to be more effective in terms of stated objectives.

A two-way analysis of variance with unequal cell frequencies (Winer, 1962, p.241) was carried out to test the null hypotheses that:

(a) After instruction the mathematics attitude scores of pretested students are no different from similar scores obtained from students who were not pretested.

(b) The attitude toward mathematics of first year College students after an open method of instruction is no different from the attitude of students who experienced a conventional method of instruction.

The customary 0.05 significance level was used. The analysis showed no significant difference between the effects of the conventional and open methods of mathematics instruction upon the post-test attitude scores (N = 124). No significant difference was found between the pretested and the unpretested groups and there was no significant interaction between the two factors.

A basic assumption of either single or multiple analysis of variance is that "...the variances within the sub group categories be homogeneous" (Popham, 1967, p.186). A test of homogeneity reported by Glass and Stanley (1970, p.374) found the sub-groups to be homogeneous with respect to the post-test attitude scores. The results of the test of homogeneity and the analysis of variance are summarised in Table 13.

TABLE 13

A : HOMOGENEITY OF VARIANCE BETWEEN GROUPS : MATHEMATICS ATTITUDE AFTER INSTRUCTION

Testing	Open Method	Conventional Method
Pretested	s^2 = 119.115	s^2 = 88.153
	$\bar{x}$ = 58.3	$\bar{x}$ = 55.03
	N = 34	N = 32
Unpretested	s^2 = 100.42	s^2 = 83.503
	$\bar{x}$ = 54.10	$\bar{x}$ = 56.85
	N = 30	N = 27

Observed value : F = 1.40 (Not significant)

Critical value : $0.95\ F_{(31,26)} = 1.90$

TABLE 13 (cont.)

B : ANALYSIS OF VARIANCE OF MATHEMATICS ATTITUDE SCORES : TEACHING METHOD X TESTING

Source	Sum of Squares	d.f.	Mean Square	F
Method	6.60139	1	6.60139	< 1
Testing	52.79821	1	52.79821	< 1
Method by Testing	276.09144	1	276.09144	2.79660 (n.s.)
Within Cells	11748.13498	119	98.72383	
TOTAL	12083.62602	122		

According to Campbell and Stanley (1963, p.25), when the Solomon model is used and it is found that "...the main effects of pretesting are negligible, it is desirable to perform an analysis of covariance with pretest scores as the covariate". The data was subjected to a single-classification analysis of covariance to test the following hypothesis: There will be no significant difference in the post course attitude of the open and conventionally taught students, when initial differences between the two groups have been adjusted with respect to their initial attitude toward mathematics (attitude pretest). A requisite of the analysis of covariance is a "...reasonable correlation between the covariate and criterion variable" (Popham, 1967, p.89). A Pearson product moment correlation coefficient, $r = 0.75$, was found between the pretest and post-test attitude scores ($N = 67$). The one-way analysis of covariance with pretest attitude scores as the covariate found no significant difference ($\alpha = 0.05$) between the effects of the two methods of mathematics instruction on the post-test attitude scores ($N = 67$). A summary of the results of the analysis of covariance is shown in Table 14.

The results of the one-way analysis of covariance show that the null form of the second hypothesis cannot be rejected.

H2 : There is no significant difference in mathematics attitude between first year College students after open instruction and first year College students after conventional instruction.

TABLE 14

ANALYSIS OF COVARIANCE ON MATHEMATICS ATTITUDE SCORES : TEACHING METHOD WITH PRETEST ATTITUDE SCORES AS COVARIATE

Source of Variation	Residuals			F
	Degrees of Freedom	Sum of Squares	Mean Square	
Between	1	135.20	135.20	2.90
Within	64	2982.20	46.59	n.s.
TOTAL	65	3117.40		

Critical value: $0.95\ F_{(1,64)} = 3.99$

B. Mathematics Comprehension

It is possible that taking a test for a second time can influence student performance on the second test. It is also possible that one of two methods of instruction will be more effective in terms of higher comprehension scores. A two-way analysis of variance was carried out to test the null hypotheses that :

(a) After instruction the mathematics comprehension of pretested students is no different from students who were not pretested.

(b) The mathematics comprehension of first year College students after open instruction is no different from students after a similar period of conventional instruction.

The customary 0.05 significance level was used.

The two-way analysis of variance with unequal cell frequencies showed no significant difference between the effects of the conventional and the open methods of mathematics instruction upon the post-test comprehension scores (N = 124). No significant difference was found between the pretested and the unpretested groups and no significant interaction was found between the two factors. The "sub group categories" were found to be homogeneous. The results of the analysis of variance and the test of homogeneity are summarised in Table 15.

TABLE 15

A : HOMOGENEITY OF VARIANCE BETWEEN GROUPS : MATHEMATICS COMPREHENSION AFTER INSTRUCTION

Testing	Open Method	Conventional Method
Pretested	s^2 = 15.84	s^2 = 12.25
	$\bar{x}$ = 16.70	$\bar{x}$ = 18.06
	N = 34	N = 32
Unpretested	s^2 = 13.69	s^2 = 10.43
	$\bar{x}$ = 16.70	$\bar{x}$ = 16.40
	N = 30	N = 27

Observed value : F = 1.21 (Not significant)

Critical value : $0.95\ F_{(33,26)} = 1.90$

B : ANALYSIS OF VARIANCE ON COMPREHENSION SCORES : TEACHING METHOD X TESTING

Source	Sum of Squares	d.f.	Mean Square	F
Method	11.12	1	11.12	< 1 N.S.
Test	19.35	1	19.35	1.46 N.S.
Method by Test	20.75	1	20.75	1.56 N.S.
Within	1573.75	119	13.22	
TOTAL	1624.99	122		

Critical value : $0.95\ F_{(1,119)} = 3.94$

As a result of the non significant findings from the two-way analysis of variance the suggestion made by Glass and Stanley (1963, p.25) to perform a one-way analysis of covariance was followed. The data was then subjected to the single classification analysis of covariance to test the following hypothesis: There will be no difference in the post course mathematics comprehension of the open and conventionally taught sudents, when initial differences between the groups have been adjusted with respect to their initial comprehension scores (comprehension pretest). A Pearson product moment correlation, r = 0.63, was found between the covariate and the criterion variable. The one-way analysis of covariance with pretest comprehension scores as the covariate found no significant difference ($\alpha = 0.05$) between the effects of the two methods of instruction on the post-test scores of mathematics comprehension (N = 67).

A summary of the results of the analysis of covariance is shown in Table 16.

TABLE 16

ANALYSIS OF COVARIANCE ON MATHEMATICS COMPREHENSION SCORES : TEACHING METHOD WITH PRETEST SCORES AS COVARIATE

Source of Variation	Residuals			F
	Degrees of Freedom	Sum of Squares	Mean Square	
Between	1	27.51	27.51	3.22
Within	64	545.65	8.52	n.s.
TOTAL:	65	573.16		

Critical value : 0.95 $F_{(1,64)} = 3.99$

The results of the two-way analysis of variance and the one-way analysis of covariance show that the null form of the third hypothesis cannot be rejected.

H3 : There is no significant difference in mathematics comprehension between first year College students after open instruction and first year College students after conventional instruction.

SEX X STUDENTSHIP

A. Mathematics Attitude

"Differences in mathematics attitude are frequently found to favour males over females at the junior high school level and beyond" (Aiken, 1976, p.296). After the period of instruction it is possible that differences in attitude exist between the sexes and between the studentship types within the sample used in this study. A two-way analysis of covariance with unequal cell frequencies and with pretest attitude scores as the covariate was carried out to test the null hypotheses that:

(a) There will be no difference in the post course attitude scores of male and female students when initial differences between the groups have been adjusted with respect to their initial attitude scores.

(b) There will be no difference in the post course attitude scores of direct entry and mature age students when initial differences between the groups have been adjusted with respect to their initial attitude scores.

The customary 0.05 significance level was used. A Pearson product moment correlation, $r = 0.75$, was found between the covariate and the criterion variable and the sub-group categories were found to be homogeneous. The results of the two-way analysis of covariance with pretest scores as the covariate show no significant difference in mathematics attitude between male and female students ($N = 67$). No significant difference was found between direct entry and mature age students ($N = 67$). There was no significant interaction between the two factors.

The results of the analysis of covariance and the test of homogeneity are summarised in Table 17.

TABLE 17

A : HOMOGENEITY OF VARIANCE BETWEEN GROUPS : MATHEMATICS ATTITUDE AFTER INSTRUCTION

Studentship	Male	Female
Direct Entry	$s^2 = 139.95$	$s^2 = 117.07$
	$\bar{x} = 49.83$	$\bar{x} = 58.35$
	$N = 6$	$N = 28$
Mature Age	$s^2 = 105.88$	$s^2 = 65.12$
	$\bar{x} = 59.14$	$\bar{x} = 55.10$
	$N = 14$	$N = 19$

Observed value $F = 2.15$ (Not significant)

Critical value : $0.95\ F_{(f,18)} = 2.77$

TABLE 17 (cont.)

B : ANALYSIS OF COVARIANCE ON MATHEMATICS ATTITUDE SCORES : SEX X STUDENTSHIP

Source	Residuals			F
	Degrees of Freedom	Sum of Squares	Mean Square	
Sex	1	27.16	27.16	< 1 N.S.
Studentship	1	0.001	0.001	< 1 N.S.
Sex by studentship	1	65.53	65.53	1.34 N.S.
Within	62	3022.05	48.74	
TOTAL :	65	3114.741		

Critical value : $0.95\ F_{(1,62)} = 3.99$

As a result of the two-way analysis of covariance the null form of hypotheses 4 and 6 must be accepted.

H4 : There is no significant difference in mathematics attitude between direct entry and mature age first year College students after mathematics instruction.

H6 : There is no significant difference in mathematics attitude between male and female first year College students after mathematics instruction.

B. Mathematics Comprehension

After instruction it is possible that differences in mathematics comprehension exist between the sexes and between the studentship types within the sample used for this study. A two-way analysis of variance with unequal cell frequencies was carried out to test the null hypotheses that:

(a) There will be no significant difference in the post course comprehension scores of male and female students.

(b) There will be no significant difference in the post course comprehension scores of direct entry and mature age students.

The customary 0.05 significance level was used.

The results of the two-way analysis of variance with unequal cell frequencies show no significant difference in mathematics comprehension between male and female students (N = 123). A significant difference was found, however, between direct entry and mature age students. An inspection of cell means showed that direct entry students had significantly higher comprehension scores than mature age students. No significant interaction was found between the two factors. The sub-group categories were found to be homogeneous with respect to the post-test comprehension scores. A summary of the results from the two-way analysis of variance and the test of homogeneity are shown in Table 18.

TABLE 18

A : HOMOGENEITY : MATHEMATICS COMPREHENSION

Studentship	Male	Female
Mature Age	s^2 = 12.45	s^2 = 11.70
	$\bar{x}$ = 16.6	$\bar{x}$ = 15.97
	N = 23	N = 38
Direct Entry	s^2 = 14.93	s^2 = 13.54
	$\bar{x}$ = 18.5	$\bar{x}$ = 17.58
	N = 12	N = 50

Observed value F = 1.28 Not significant

Critical value: 0.95 $F_{(11,37)} = 2.05$

B : ANALYSIS OF VARIANCE : SEX X STUDENTSHIP

Source	Sum of Squares	d.f.	Mean Square	F	
Within cells	1537.63	119	12.92		
Sex	3.44	1	3.44	< 1	N.S.
Studentship	83.45	1	83.45	6.46	
Sex by Studentship	0.47	1	0.47	< 1	N.S.
TOTAL:	1624.99	122			

Critical value: 0.95 $F_{(1,119)} = 3.93$

This result shows that the null hypothesis must be rejected.

H5 : Immediately after instruction the mathematics comprehension of direct entry students is no different from the mathematics comprehension of mature age students.

It was then decided to use a one-way analysis of variance to find if there was a significant difference in comprehension between direct entry and mature age students before instruction commenced. The one-way analysis of variance found a significant difference ($p < 0.05$) in mathematics comprehension between the two groups before instruction. A summary of the results is shown in Table 18A.

TABLE 18A

A : ONE-WAY ANALYSIS OF VARIANCE ON MATHEMATICS COMPREHENSION

Source	Sum of Squares	d.f.	Mean	F
Within cells	1026.85	65	27.79	
Studentship	90.62	1	90.62	5.74 ($p < 0.05$)
TOTAL:	1116.47	66		

Critical value: $0.95\ F_{(1,65)} = 3.99$

B : MATHEMATICS COMPREHENSION SCORES

	Direct Entry Students	Mature Age Students
mean $\bar{x}$ =	13.24	10.90
variance s =	14.90	16.65
N =	34	33

In view of the findings from the two-way analysis of variance on post-test comprehension scores and the one-way analysis of variance on pretest scores, it was decided to use an analysis of covariance to find out whether there was a significant difference in comprehension between direct entry and mature age students after an adjustment had been made for initial comprehension differences before instruction. A Pearson product moment correlation, $r = 0.62$, was found found between the covariate and criterion variable. The two-way analysis of covariance (sex by studentship) with pretest comprehension scores as the covariate found no significant difference in mathematics comprehension after instruction between the direct entry and mature age students ($N = 67$). No significant interaction was found between the sex and studentship variables. A summary of the results from the two-way analysis of covariance is shown in Table 18B.

TABLE 18B

ANALYSIS OF COVARIANCE ON MATHEMATICS COMPREHENSION SCORES : SEX X STUDENTSHIP

Source	Sum of Squares	d.f.	Mean Square	F	
Sex	8.85	1	8.85	1.03	n.s.
Studentship	0.03	1	0.032	< 1	n.s.
Sex x Studentship	37.72	1	32.72	3.80	n.s.
Within cells	532.66	62	8.59		
TOTAL:	579.22	65			

Critical value: $0.95\ F_{(1.64)} = 3.99$

The findings of the one-way analysis of variance on comprehension scores and the two-way analysis of covariance on comprehension scores with pretest comprehension scores as the covariate, reported in Table 18A and Table 18B respectively, suggest that the significant difference in the post course comprehension scores between the two studentship groups is not a result due to either of the methods of instruction.

SEX X STUDENTSHIP X METHOD

A. Mathematics Attitude

It is possible that significant interactions on the post course attitude scores exist between the major factors considered in this study. The previous analyses reported the main effects of these factors upon either the attitude scores or the comprehension scores. For this purpose either one or two-way analyses of variance ~~of~~ or covariance had been used. A three-way analysis of covariance with unequal cell frequencies was used to examine main and interaction effects after an adjustment for initial differences in attitude towards mathematics. A Pearson product moment correlation, $r = 0.67$, was found between the covariate and criterion variable ($N = 67$). The test for homogeneity (Glass and Stanley, 1970, p.374) showed no significant difference between the sub-group categories.

The three-way analysis of covariance with unequal cell frequencies and with pretest scores of mathematics attitudes as the covariate, found no significant difference ($p < 0.05$) in the scores of mathematics attitude between the open and conventional groups after instruction (N = 67). There was no significant difference in the attitude scores of male and female students nor of direct entry and mature age students. There were no significant interactions.

The results of the three-way analysis of covariance and the test for homogeneity are summarised in Table 19.

TABLE 19

A : HOMOGENEITY OF VARIANCE : MATHEMATICS ATTITUDE AFTER INSTRUCTION

Studentship	Male		Female	
	Open	Conventional	Open	Conventional
Mature Age	$\bar{x}$ = 59.3 s^2 = 93.9 N = 10	$\bar{x}$ = 58.75 s^2 = 176.89 N = 4	$\bar{x}$ = 55.36 s^2 = 72.35 N = 11	$\bar{x}$ = 54.75 s^2 = 64.16 N = 8
Direct Entry	$\bar{x}$ = 58.54 s^2 = 96.04 N = 2	$\bar{x}$ = 46.2 s^2 = 76.21 N = 4	$\bar{x}$ = 59.33 s^2 = 193.2 N = 12	$\bar{x}$ = 57.62 s^2 = 65.93 N = 16

Observed value: F = 3.01 (Not significant)

Critical value: 0.05 $F_{(11,7)}$ = 3.60

B : ANALYSIS OF COVARIANCE ON POST COURSE ATTITUDE SCORES : SEX X STUDENTSHIP X METHOD

Source	Sum of Squares	d.f.	Mean Square	F
Sex	28.40	1	28.40	< 1
Studentship	0.0006	1	0.0006	< 1
Method	137.1	1	137.1	3.10
Sex x Studentship	35.72	1	35.2	< 1
Sex x Method	128.32	1	128.32	2.90
Studentship x Method	142.10	1	142.10	3.21
Sex x Studentship x Method	79.50	1	75.50	1.79
Within cells	2561.90	58	44.17	
TOTAL:	3113.04	65		

Critical value: 0.95 $F_{(1,58)}$ = 4.01

It can be concluded from the results of the three-way analysis of covariance that the following null hypotheses must be accepted.

(a) The mathematics attitude of first year College students after open instruction is no different from the attitude of students after conventional instruction with an adjustment for initial differences in attitude to mathematics.

(b) The mathematics attitude of first year male students after instruction is no different from female students after an adjustment for initial differences in attitude to mathematics.

(c) The mathematics attitude of mature age students after instruction is no different from direct entry students after an adjustment for initial differences in attitude to mathematics.

These conclusions reinforce the findings of the one- and two-way analyses used earlier in this study. In addition, the three-way analysis of covariance on attitude scores found no significant interactions between the three factors.

B. Mathematics Comprehension

It is possible that significant interactions on post course comprehension scores exist between the major factors of this study. Analyses which had been used earlier in this study were either one- or two-way anlyses of variance or covariance. A three-way analysis of covariance with unequal cell frequencies was used to examine the main and interaction effects of three factors upon mathematics comprehension scores after an adjustment for initial differences in mathematics ability. A Pearson product moment correlation, $r = 0.54$, was found between the covariate and criterion variable. The F value obtained by dividing the smallest group variance into the largest group variance is not statistically significant ($\alpha = 0.05$). The variances of the sub-group categories are homogeneous.

The three-way analysis of covariance on comprehension scores with unequal cell frequencies and with mathematics ability scores as the covariate found a significant difference ($\alpha = 0.05$) in the mathematics comprehension scores of the open and conventional methods of instruction. An examination of cell means shows that students who experienced the conventional method of instruction had significantly higher comprehension scores than did the students who experienced the open method of instruction. There was no significant difference between the mathematics comprehension scores of male and female students nor between the scores of mature age and direct entry students. There were no significant interactions. A summary of the results of the three-way analysis of covariance, the cell mean comprehension scores, and the test for homogeneity is shown in Table 20.

TABLE 20

A : HOMOGENEITY OF VARIANCE : MATHEMATICS COMPREHENSION AFTER INSTRUCTION

Studentship	Male		Female	
	Open	Conventional	Open	Conventional
Mature Age	$\bar{x}$ = 15.62 s^2= 12.39 N = 13	$\bar{x}$ = 19.40 s^2= 5.31 N = 5	$\bar{x}$ = 16.25 s^2= 11.97 N = 12	$\bar{x}$ = 16.75 s^2= 8.53 N = 12
Direct Entry	$\bar{x}$ = 16.67 s^2= 26.32 N = 3	$\bar{x}$ = 19.00 s^2= 15.60 N = 7	$\bar{x}$ = 18.05 s^2= 15.23 N = 18	$\bar{x}$ = 18.17 s^2= 10.11 N = 23

Observed value: F = 4.95 (Not significant)

Critical value: $0.95\ F_{(2,4)} = 6.94$

B : ANALYSIS OF COVARIANCE ON POST COURSE MATHEMATICS COMPREHENSION SCORES : SEX X STUDENTSHIP X METHOD

Source	Sum of Squares	d.f.	Mean Square	F
Sex	5.52	1	5.52	< 1
Studentship	0.41	1	0.41	< 1
Method	45.37	1	45.37	5.33395 ($p < 0.05$)
Sex x Studentship	2.02	1	2.02	< 1
Sex x Method	32.15	1	32.15	3.77962
Studentship x Method	0.75	1	0.75	< 1
Sex x Studentship x Method	9.63	1	9.63	1.13207
Within cells	714.64	84	8.50	

Critical value: $0.95\ F_{(1,84)} = 3.96$

One finding from this three-way analysis of covariance appears to be inconsistent with results obtained from earlier analyses. The results shown in both Table 15 and Table 16 indicate that the null form of the third hypothesis should be accepted. The results from the three-way analysis of covariance suggest that the null form of the third hypothesis should be rejected. It follows that the conclusion to accept the null form of the third hypotheses must be treated with caution.

SUMMARY

The analyses made in this study report findings which concur with the results obtained in other similar investigations (Aiken, 1961; Dutton, 1962; Singleton, 1972). This study reports the following findings:

(i) After instruction the mathematics comprehension and mathematics attitude scores of first year students were significantly higher ($p < 0.001$) than similar scores obtained before instruction.

(ii) After instruction the attitude and comprehension scores of the pretested students did not differ significantly ($\alpha = 0.05$) from those obtained from the students who were not pretested.

(iii) After instruction the attitude scores of students in the open group were no different ($\alpha = 0.05$) from the scores of students in the conventional group. The same result was obtained after an adjustment had been made for initial differences in attitude to mathematics.

(iv) After instruction the comprehension scores of students in the open group were no different ($\alpha = 0.05$) from the scores of students in the conventional group. The same results were obtained after an adjustment had been made for initial differences in mathematics comprehension. When an adjustment was made for initial differences in the wider domain of mathematics ability the post course comprehension scores of students in the conventional group were significantly higher ($p < 0.05$) than the comprehension scores of students in the open group.

(v) After instruction the attitude and comprehension scores of male students did not differ significantly ($\alpha = 0.05$) from the scores of female students. This same result was obtained after an adjustment had been made for initial differences in attitude to mathematics and comprehension.

(vi) After instruction the attitude scores of mature age students did not differ significantly ($\alpha = 0.05$) from the scores of direct entry students. This same result was obtained after an adjustment had been made for initial differences in attitude to mathematics.

(vii) After instruction the mathematics comprehension scores of direct entry students were significantly higher ($p < 0.05$) than the scores of mature age students. When an adjustment was made for initial differences in mathematics ability there was no significant difference ($\alpha = 0.05$) between the two groups.

CHAPTER 5

CONCLUSIONS

This study was concerned primarily with the effects of two instructional methods upon the mathematics attitude and the mathematics comprehension of first year teachers college students. Three groups of hypotheses were formulated. The first of these postulated that the attitudes of students toward mathematics would be more favourable after instruction than their attitudes before instruction. The second group proposed a differential achievement of the instructional objectives for each method of instruction. It was expected that the open method of instruction would be more effective in terms of student attitude toward mathematics and student comprehension of mathematics content, than the conventional method of instruction. The third group put forward comparisons between two pairs of factors. After instruction it was postulated that the mathematics attitude and comprehension scores of male students would be no different from those of female students. Similarly it was postulated that there would be no difference between the scores of mature age and direct entry students.

Attitude and Comprehension : Instruction Effects

Several studies have reported an improvement in the attitude of students toward mathematics after a period of instruction (Collier, 1970; Taylor, 1970; Singleton, 1972). This conclusion is also suggested by the findings of this study. The post course attitude scores of sixty-seven pretested first year students from both instruction groups were significantly higher ($\alpha = 0.05$) than their pretest attitude scores. It has been argued that higher scores can result from the taking of a test for a second time (Campbell and Stanley, 1963). In this study the post course attitude scores of the pretested students were no different ($\alpha = 0.05$) from the scores of students who were not pretested. It is concluded that pretesting had no significant effect upon the post course scores of attitude toward mathematics. It might be argued that improvement effects which may have resulted from the taking of a test for a second time were less likely to have occurred when there was a ten week time interval between the two tests. It was also possible that pretesting was less likely to effect a second performance when that test was in the affective rather than the cognitive domain. These arguments may account for a non-significant effect of pretesting upon the post course attitude scores.

It was thought that an open method of instruction which provided the students with a choice of different teaching strategies would more appropriately meet the needs of individual learning styles than would the conventional method which consisted of one teaching strategy. The student was also able to choose from several domains of mathematics content in the open method of instruction. It was believed that this provision would more adequately satisfy individual student needs and interests than would the conventional method which consisted of a fixed domain of content. The open group of students was then expected to achieve higher comprehension scores and show more favourable attitudes to mathematics than the conventional group. This study found no significant difference ($\alpha = 0.05$) between the post course attitude scores of students in the open and in the conventional programmes. The relatively short duration of both mathematics programmes may have had different effects upon the attitude scores of students in the two groups. There were no students who had previously experienced an open programme. It appeared that students in the open group had difficulty getting a sequence of learning activities established. In the first two weeks many students in this group had found decision-making a difficult process. During that period thirty-seven students had requested more specific directions from the teaching staff to help with their selection of content and method of instruction. Throughout the first four weeks of the mathematics programme, staff had been asked constantly to "approve" the curriculum decisions of the students in the open group. An analysis of their work schedules revealed that more than sixty per cent had changed their area of content at least once in the first two weeks. Thirty per cent had changed direction more than once. It also appeared that the open group students had been reluctant to make individual decisions concerning their selection of content and teaching method. Most often their final choice had resulted from discussion with other students in their group. Eighty per cent of the open group had agreed that their choice had followed a decision made previously by another student. It appeared that these behaviours expressed their concern with the open method of teaching. This lack of familiarity or experience with curriculum decision-making had seemed to create anxieties which may have had an effect upon their attitude to mathematics. In their school environment most of these students had experienced teacher-directed learning situations. If specific directions had been given to the open group students they may have been less anxious about the method of instruction. The conventional programme had been teacher-directed. The students had not been required to make decisions concerning the content or method of teaching. All of these students had experienced this teaching environment in the past and the concerns expressed to staff by these students related to matters of content. It follows that the expected outcomes of the open method in terms of higher attitude scores and higher comprehension scores than those scores obtained in the conventional programme, may have been affected adversely by the short duration of the programme. This differential effect may have been overcome with a longer period of instruction. It is possible that the open group of students would have obtained higher scores of attitude to mathematics. It is not possible to attribute the improvement in attitude scores to one particular teaching method. It may be argued that any style of mathematics instruction is likely to result in improved scores of student attitude to mathematics. Similarly the comprehension scores are also likely to show improvement after instruction.

Three other factors not investigated in this study have possibly contributed to the development of these more favourable student attitudes to mathematics.

1. Successful achievement in mathematics. Studies (Dutton, 1962; Reys and Deion, 1968) have shown that a relatively high proportion of first year students have not mastered the basic concepts of primary mathematics at the time of their entry to Teachers College. Fifty per cent of the first year students used in this study obtained a mathematics ability score which would have located a twelve year old below the 70th percentile. Within the content domains specified for this study, sixty per cent of the students obtained an intial comprehension score of less than fifty per cent. Some studies (Neale, 1969; Whipkey, 1970; Wilson, 1973) have claimed that unsuccessful

achievement has an effect upon the students' attitude to mathematics. This study found that students in both instruction groups achieved success in their mathematics learning. After instruction their mathematics comprehension scores ($\bar{x}$ = 16.8, s^2 = 13.29) were significantly (α = 0.05) higher than their pre-course comprehension scores ($\bar{x}$ = 11.97, s^2 = 16.4). A number of different factors may have contributed to this effect but a common characteristic of both methods of instruction was the provision of tutorial sessions. In the conventional programme the teaching staff had given individual assistance to the students in scheduled sessions. This assistance may have contributed to the achievement success of these students. The nature of the open programme had been such that each session became a tutorial, the students had helped one another with their problem solving activities in small group formation. The staff had assisted students whenever they were requested to explain or clarify particular concepts. This shared approach to problem solving may have contributed to the achievement success of the open group of students.

The use of manipulative materials used as explanatory models in the conventional programme and as individual learning aids in the open programme may also have contributed to the achievement success of some students in this study.

It is also possible that motivation to learn is high with students new to an institution. All students used in this study were new arrivals to the College. Some students may have achieved success in their mathematics learning as a result of this motivation due to the new environment.

It may be argued that any one or combination of these factors may have had a positive influence upon student comprehension of mathematics content. Many studies claim a relationship between achievement and attitude. It is possible that the successful achievement of the students used in this study may have helped develop favourable student attitudes to mathematics.

<u>2. The influence of the teaching staff</u>. In general it is recognized that teacher behaviour does influence student performance. Although a different role had been expected of the teaching staff in each method of instruction, they did interact with the students in both programmes. The students in both instruction groups often requested that

some mathematical ideas be clarified. They also asked for assistance with mathematical problems or activities. It is likely that these staff-student communications facilitated the students learning of mathematics. If there is a relationship between achievement and attitude it can be argued that these staff-student communications had some favourable effect upon the students attitude to mathematics.

Some other studies (Flanders, 1970) have claimed that often the tone or manner of the teachers communications can affect the learnings and attitudes of the students. In their written evaluations of the mathematics programmes more than ninety per cent of the students had used the words "helpful", "friendly", "supportive" and "approachable" as descriptions or staff behaviour. It is possible that these behaviours had facilitated the development of favourable student attitudes toward mathematics.

When a comparison is made between teaching styles it is reasonable to expect different outcome effects from student classes with different teachers. It may be argued that the use of six staff in both programmes had jeopardized a valid comparison between the two methods of mathematics instruction. There were differences in the "presage characteristics" (Dunkin and Biddle, 1974, p.39) of the teaching staff. These differences may account for any different attitude and comprehension outcomes between the six teaching sections. It was not a purpose of this study to analyse outcomes between the teaching sections. The major comparison was made between the two method groups. The same staff had been randomly assigned to a teaching section in each method group and had participated in the planning of both mathematics programmes. All had obtained university degree qualifications in mathematics and education. Each had completed at least seven years teaching in schools and at least three years in a Teachers College. Their scores of attitude to mathematics ranged from seventy-nine to eighty-two ($\bar{x}$ = 80.33, s^2 = 1.47) and were described as positive.

In view of these similarities and the equivalent responsibilities shared by staff in both programmes, it was assumed that the effects due to staff variations on student attitude and comprehension had been constant across both of the method groups.

3. Unexpected events. During the period of mathematics

instruction two unexpected events had occurred which may have caused an upward movement in the post-course scores of student attitude toward mathematics. An announcement had been made by the Minister of Education (W.A.) in March 1977 which stated that not all students in training would obtain a permanent teaching position immediately after graduation. This announcement had caused concern among the student population. They had concluded that appointment to a permanent position would be dependent upon College grades. After the announcement the students had regarded any college requirement of an evaluative kind as job-related. Some students may have thought that their replies to the post course attitude questionnaire would have an effect upon their future opportunities for permanent employment. It follows that some students may have replied in an acquiescent manner, almost independent of the content of the items. This tendency to "agree" to items which the respondent believes reflect desirable attitudes may have resulted from the Minister's statement. It follows that the total score of these response sets would be artificially high.

Some students may have worked harder as a result of the Minister's statement. Possibly these students recognised a need for high grades if they were to obtain a permanent position after graduation. Higher mathematics comprehension scores may have resulted from the increased work effort of some students.

The results of a nationwide survey into literacy and numeracy in Australian schools had been published in 1976 (Keeves and Bourke, 1976). Several newspapers had publicized these results and the quality of mathematics education in Australian schools became a debated issue. It is possible that some students had been influenced by the flood of articles which had stressed the importance of mathematics education. Their attitude to the value of mathematics education may have been changed as a result of the public debate.

The attitude questionnaire used in this study contained several "value" items and these could have been endorsed more positively by some students as a result of the numeracy report. It is unlikely that the students' enjoyment of mathematical activity was affected by publication of the numeracy report. It is unlikely that the report had any affect upon student responses to the "enjoyment" items contained in the attitude questionnaire.

Attitude and Comprehension : Sex Effects

Differences in mathematics attitude have been found to favour males over females at the secondary school level and beyond (Keeves, 1973; Simpson, 1974; Hilton and Berglund, 1974). This study found no significant difference ($\alpha = 0.05$) between the attitudes of male and female students toward mathematics. This is a reasonable result if there is a relationship between mathematics ability and mathematics attitude. A comparison between the mathematics ability scores of male students ($\bar{x} = 33.43$, $s^2 = 4.24$, $n = 31$) and female students ($\bar{x} = 32.49$, $s^2 = 5.94$, $n = 69$) had shown a close matching. It may be argued that males with very high ability in mathematics do not choose to enter a primary teachers college. This would help to explain the equivalent ability matching between the two groups of students. A correlation coefficient $r = 0.67$ was found between the scores of mathematics ability and post course comprehension. If there are relationships between attitude and comprehension and between ability and comprehension, it is possible that a relationship exists between ability and attitude. If there is no difference between the mathematics ability scores of male and female students it appeared reasonable to expect no difference between their scores of attitude toward mathematics.

This argument may have been strengthened had there been a high positive correlation between the scores of mathematics ability and attitude toward mathematics. An analysis of these two sets of scores shows two situations which may account for the relatively low correlation coefficient ($r = 0.36$, $n = 93$) obtained in this study. Seventeen students with relatively high ability scores ($x > 36$) obtained relatively low scores ($x < 50$) on the attitude scale. Twelve of these students were mature age entrants and had not been in a mathematics learning environment for a number of years. It was possible that some of these mature age students were apprehensive about their return to mathematics education. Their anxiety may have been expressed with negative responses to an excess number of items in the attitude scale after a consideration of their mathematics ability scores.

A second situation was found where ten students with relatively low ability scores ($x < 28$) obtained relatively high scores on the attitude scale ($x > 60$). It is possible that the motivation created by their entry into a new institution had caused some of these students to respond positively to an excess number of items after a consideration of their ability scores. It is also possible that some students had replied to the attitude questionnaire in a manner which they perceived as desirable rather than as a reflection of their attitude to mathematics. The attitude scores of these students may have been excessively high in comparison with their scores of mathematics ability.

A reasonable correlation ($r = 0.68$, $n = 122$) was found between the post course scores of comprehension and attitude to mathematics. This finding tended to support the hypothesis that there is a relationship between achievement and attitude. As there was no significant difference ($\alpha = 0.05$) between the post course comprehension scores of male and female students, it appeared reasonable to conclude that the male and female students had experienced a similar success in their mathematics learning. If there is a relationship between success and attitude toward mathematics it is also reasonable that there was no difference between the attitude scores of male and female students.

Attitude and Comprehension : Studentship Effects

It seemed reasonable to expect significant differences in attitude to mathematics and mathematics comprehension between the mature age and the direct entry students. Some of the mature age students had resigned from other employment to enter Teachers College. Eighty per cent of these students were married at the time of entry compared with the two per cent of direct entry students. Their acceptance of low earnings together with marital responsibilities may have been a reflection of a strong motivation to become teachers. Direct entry students may not have had the same motivation. McKeachie (1963, p.1119) states that "Student learning is closely tied to motivation". It appeared reasonable to expect differences between the two groups of students.

This study found no significant difference in attitude to mathematics between the mature age and direct entry students. It is possible that other factors such as teacher influence and achievement success which affected both groups had a stronger effect upon their attitude to mathematics than did the motivation to become a teacher. It was considered that differences in initial attitudes may have had an effect upon this finding. After an adjustment was made for any differences in initial attitudes toward mathematics, no significant difference in post course attitudes was found between the mature age and the direct entry students.

More than half of the mature age students had not experienced a mathematics learning environment for at least eight years. These students were not likely to have been familiar with the concepts and terminology of the 'new' mathematics. Guilford (1952, p.142) has demonstrated that the loss of subject knowledge over one year exceeds twenty-five per cent. The mature age students were likely to have forgotten mathematical concepts learned at school. All direct entry students had experienced a secondary school mathematics programme throughout the previous year. They were likely to be familiar with the concepts and language of 'new' mathematics. This familiarity may have had an effect upon their post course comprehension scores. A significant difference in comprehension was expected between the two groups of students. This study found the mathematics comprehension scores of direct entry students to be significantly higher than the scores of mature age students. It was evident that there were item similarities in the tests of mathematics ability and mathematics comprehension. Some of these items had required the students to have a familiarity with some concepts and terms of the 'new' mathematics. The peformance of the mature age students on these particular items may account for their inferior comprehension scores before and after instruction. The disappearance of this performance difference between direct entry and mature age students after an adjustment had been made for differences in the mathematics ability between the two groups tends to support this argument.

Additional information about the relative performances of direct entry and mature age students may have resulted from the use of mathematics aptitude scores as the covariate. It is more likely that aptitude scores would be independent of the time lapse in the students' mathematical experiences than the ability scores used as the covariate in this study.

Interaction Effects

There were no significant interaction effects between the major factors in this study. The interaction between the sex and studentship factors on the post course comprehension scores of the sixty-seven pretested students after an adjustment had been made for differences in initial comprehension scores was almost significant. Direct entry students who obtained higher scores on the post course comprehension test tended to be male and conversely, mature age students with the higher performance were female. This result is not conclusive. The F-ratio was not quite significant and when an adjustment was made for differences in the initial ability of the students, the interaction between the sex and studentship factors was not significant. It was possible that the relatively small number of direct entry males who were pretested (n = 6) had a disproportionate influence upon the results of these analyses of covariance. An analysis of variance on the post course comprehension scores of all students in the sample (n = 123) found no significant interaction between the two factors.

LIMITATIONS OF THE STUDY

The students in this study showed a significant improvement in their attitude to mathematics and their comprehension within the specified domains of mathematics content in both programmes of instruction. Although there has been considerable argument for (Scriven, 1967) and against (Cronbach, 1963) comparative evaluations, the programmes were compared in terms of the pre-specified goals. There was no difference between the two methods of instruction. Neither method of instruction was evaluated as it had been recognized that pretesting and post-testing for the achievement of pre-specified objectives did not constitute a complete evaluation. Several writers have stated the need to look for side effects when a method of instruction is evaluated (Dyer, 1967; Stake, 1967; Scriven, 1971; Hogben, 1973).

The short duration of both programmes required that the results due to instruction be treated with some caution. The time required for students in the open programme to adapt to their new learning environment has been discussed previously in this study. In addition the domains of mathematics content chosen for both programmes represented a small sample of content from the primary mathematics curriculum. Although the students from both instruction groups showed a significant improvement in their comprehension of mathematics content, it was not possible to state that mastery of primary mathematics content had been achieved.

The attitude improvement from both groups of students occurred over the period of instruction. This result was also viewed with some caution. The possibility that students had responded to the attitude items in an acquiescent manner has been discussed earlier in this investigation. The permanency of their change in attitude to mathematics was not investigated. It is possible that those students who showed a change in attitude did not previously hold a firm conviction about mathematics or mathematics teaching. These students may have been more readily influenced to change their attitude than others who held firm convictions. It is likely that students without strong convictions will just as readily reverse their opinions in a different situation in the future. It cannot be claimed that those students will enter primary teaching with their current attitude to mathematics and comprehension of content. It is possible that future events will modify existing attitudes and comprehension.

Romberg (1969, p.481) has stated that "Conceptual and methodological problems are particularly acute in the study of attitudes. A theoretical formulation is needed which conceives of attitudes as a set of moderation variables that affect a subject's response to mathematical situations in observable and predictable ways". Recent developments in the construction of attitude scales include the multi-dimensional instruments of McLure (1971) and Sandman (1974). It is likely that other constructs are components of the "attitude toward mathematics" construct. Sandman (1974) identified six in his forty-eight item inventory and Aiken's (1974) instrument was scored on two scales. Three component constructs of the attitude toward mathematics concept were included in the scale used for this investigation: enjoyment of mathematics, value of mathematics and perceptions of teaching primary mathematics. Separate construct scores were not obtained in this study. It may be argued that the use of a single, global score to represent each students attitude to mathematics is unrealistic. It is possible that students would become better teachers of mathematics after a specific construct of the attitude toward mathematics concept had been modified. The modification of some attitude constructs may have no affect upon the teaching effectiveness of these future teachers of primary mathematics. The identification of relevant component constructs together with the procedures that modify existing attitudes toward mathematics may be the subject of further research.

The final selection of items to be included in the attitude scale used for the purposes of this investigation, was dependent upon a test of item fit with the Andrich (1976) multiplicative binomial response model. It has been found that estimates of item fit may vary with different sized samples (Andrich, 1976). It is possible that some items of the scale may not fit the model with a different sized sample of first year teachers college students. The identification of these items may be the subject of further research.

RECOMMENDATIONS

The major purpose of a mathematics education programme at a primary teachers college is to prepare students to become effective teachers of primary mathematics. It has been argued that effective teachers of primary mathematics need to have positive attitudes to mathematics and a mastery of primary mathematics content. It is then likely that a college mathematics programme will be concerned with the improvement of existing student attitudes to mathematics and their existing comprehension of mathematics content. It is also likely there will be some focus upon the methodologies of teaching mathematics to children in the primary school. This study found a significant improvement in the attitude of students to mathematics after instruction. It also found a significant gain in student comprehension scores after instruction. There is a general recognition of a relationship between attitude and achievement.

College mathematics courses with a strong orientation toward content will possibly effect significant gains in student comprehension of mathematics. If this achievement is seen as worthwhile by the students it may result in the development of favourable attitudes to mathematics.

Within a college course of mathematics instruction the teaching staff needs to be able to provide a programme which is suitable for all of the students who take part. It was evident from the pre-course test results in this study that differences exist in the mathematics comprehension of first year students on entry to teachers college.

The present study found no significant difference in the attitude and comprehension scores of male and female students either before or after instruction. It follows that sex differences need not be a consideration in the planning of teachers college courses of mathematics which are concerned with the development of positive attitudes and the development of comprehension.

Although there was no difference in the attitude scores of direct entry and mature age students, there was a significant difference in their comprehension scores both before and after instruction. Except for the comprehension scores of these two groups, it appeared that student differences in attitude and comprehension were dependent upon their previous experience in mathematics and were not specifically characteristic of any particular group of students. The comprehension performance of the mature age students appeared to result from their relative unfamiliarity with the language and concepts of 'new' mathematics content. Some special provision needs to be made for these students. In order to avoid the partition of first year students into two separate studentship groups, an introductory course designed to overcome the mature age students relative unfamiliarity with the new mathematics might be implemented before the major mathematics education programme has begun. This could be achieved if the major programme was delayed until after the conclusion of the introductory course for mature age students.

A provision has been suggested to provide for the comprehension differences found between the mature age and direct entry students. Another provision also needs to be made for the differences that were found amongst first year students. The identification of these differences is dependent upon the construction of two valid and reliable measuring instruments.

The first instrument is necessary to identify domains of mathematics which differentiate the students comprehension of mathematics. If the major mathematics programme is concerned with an improvement of student comprehension across all the domains of primary mathematics content then the Progressive Achievement Test (Reid and Hughes, 1975) may be considered as an appropriate instrument. It may be preferable to administer this test prior to the major mathematics programme for all students but after the conclusion of any introductory course for the mature age students. This would avoid a partition effect between mature age and direct entry students in the major programme as the special difficulties of the mature age students may have then been overcome. Interaction between these two groups of students in a mathematics learning environment would then be possible.

It has been recognized that there is a relationship between attitude and achievement. Although this study found no difference in mathematics attitude between mature age and direct entry students, a significant difference was found between the comprehension scores of these two student groups. It is possible that the motivation effects of a new institutional environment for the mature age students who had made financial and personal sacrifices to enter a teachers college had sufficient influence upon their expressions of mathematics attitude to overcome any attitudinal effects due to their poorer comprehension performances. The implementation of an introductory mathematics course for mature age students might result in a minimum finding of no difference between the comprehension scores of the two groups of students.

The second instrument is needed to identify student differences in attitude to mathematics. The attitude scale developed for the present study may be considered for this purpose. This scale contains items which put forward mathematical situations regarded as relevant for future teachers of primary mathematics in Australia and New Zealand. Three constructs of the attitude to mathematics concept were represented by the items on the scales. It is possible to identify those constructs which have reflected significant changes in the students attitude to mathematics. The attitude scale should be administered before and after the period of instruction. If the mature age students are to experience an introductory mathematics course it may be necessary for them to respond to the scale on three occasions: before and after the introductory course and again at the conclusion of the major programme. The permanency of any change in attitude to mathematics after instruction may be the subject of further research.

The results of the present study show no significant differences that can be attributed to the different methods of instruction. After consideration of the provisions made in the open programme for student differences, this result was not expected. This finding may have been due to the relatively short duration of the programme as was discussed earlier in this study. It is most likely that differences in attitude and comprehension will be found amongst future intakes of first year college students. A programme designed to meet these differences may also provide the students with a choice of content and method of instruction but it may be considered to continue the mathematics instruction for a longer period of time. It is likely that an experimental programme which requires the students to experience a different learning style will necessitate a reasonable time period for the process of adaptation to the new strategy.

The open method of mathematics instruction did provide some students with the experience of different methods of instruction. These students may be equipped to make better provision for pupil differences in their future mathematics classrooms.

APPENDIX A

RESEARCH QUESTIONNAIRE AND ANSWER SHEET

Note to Students:

i) This is not a test. There are NO right or wrong answers. Just answer as honestly as you can.

ii) Results of this questionnaire can help with the design of Mathematics Education Courses

iii) On your answer sheet, circle the letter which best describes the answer you wish to make to a particular statement.

- A strongly agree
- B agree
- C disagree
- D strongly disagree.

1. I want to have a sound knowledge of primary mathematics content.
2. I want to have a teaching expertise in primary mathematics.
3. I am not enthusiastic about teaching mathematics.
4. I lack confidence to teach mathematics in the upper primary school.
5. I want to know how children best learn mathematics.
6. I want to read many articles and readings related to mathematics teaching.
7. I want to find out as much as I can about mathematics.
8. Mathematics is hard to understand.
9. I intend to put at least as much effort into my mathematics teaching as any other subject.
10. I do not intend to subscribe to journals concerned with mathematics teaching.
11. I will work hard to be successful in my mathematics courses.
12. Mathematics content should be a compulsory course for teachers college students.
13. If given a choice I would still want to take a primary mathematics content course at college.
14. If methods of teaching mathematics in the primary school was an option I would still want to take the course.
15. Mathematics is not an essential experience for primary pupils.
16. Mathematics is a boring experience.

17. I will work as hard in mathematics as in other courses.

18. If mathematics was one of several college tasks to be completed at much the same time then generally,

    a) I would attend to mathematics first

    b) I would attend to mathematics near the beginning

    c) I would attend to mathematics near the end

    d) I would attend to mathematics last.

19. I should know different ways of teaching mathematical ideas.

20. Mathematics is no more important than most other subjects for primary pupils.

21. I am apprehensive about undertaking electives in mathematics content.

22. At the conclusion of my college course I intend to keep up with developments in mathematics education.

23. I want to voluntarily attend extra courses in mathematics designed to improve my understanding and teaching competence.

24. There is no justification for mathematics courses in a primary teachers college.

25. There has been no enjoyment for me in recent mathematical activities.

26. Mathematics is not one of my most preferred subjects.

27. I want to continue my mathematics education next year.

28. If a mathematics club was to be established in my primary school then I would want to participate.

ANSWER SHEET

GROUP	IP [ ]	
SEX	M [ ]	F [ ]
STUDENTSHIP	DE [ ]	MA [ ]

CODE NUMBER

1	2	3	4	5	6	7	8

1.	A	B	C	D	15.	A	B	C	D
2.	A	B	C	D	16.	A	B	C	D
3.	A	B	C	D	17.	A	B	C	D
4.	A	B	C	D	18.	A	B	C	D
5.	A	B	C	D	19.	A	B	C	D
6.	A	B	C	D	20.	A	B	C	D
7.	A	B	C	D	21.	A	B	C	D
8.	A	B	C	D	22.	A	B	C	D
9.	A	B	C	D	23.	A	B	C	D
10.	A	B	C	D	24.	A	B	C	D
11.	A	B	C	D	25.	A	B	C	D
12.	A	B	C	D	26.	A	B	C	D
13.	A	B	C	D	27.	A	B	C	D
14.	A	B	C	D	28.	A	B	C	D

APPENDIX B

ATTITUDE ITEMS IN POSITIVE FORM : AFFECTIVITY ORDER

Item No.	Item	Affectivity Estimates		
		Raw	Scaled	Scaled Standard Error
24	*There is justification for mathematics courses in a Primary Teachers College.	-1.36	44.0	0.7
15	*Mathematics is an essential experience for primary pupils.	-1.21	44.5	0.7
5	I want to know how children best learn mathematics.	-1.18	44.6	0.7
1	I want to have a sound knowledge of primary mathematics content.	-1.11	45.0	0.7
11	I will work hard to be successful in my mathematics courses.	-0.73	46.7	0.6
19	I should know different ways of teaching mathematical ideas.	-0.71	46.8	0.6
9	I intend to put at least as much effort into my mathematics teaching as any other subject.	-0.56	47.5	0.6
2	I want to have a teaching expertise in primary mathematics.	-0.40	48.2	0.5
17	I will work as hard in mathematics as in other courses.	-0.37	48.3	0.5
12	Mathematics content should be a compulsory course for primary teachers college students.	-0.22	49.0	0.5
27	I want to continue my mathematics education next year.	-0.03	49.8	0.5
13	If given a choice I would still want to take a primary mathematics content course at Teachers College.	-0.03	49.8	0.5
14	If 'methods of teaching mathematics in the primary school' was an option I would still want to take the course.	-0.03	49.8	0.5
16	*Mathematics is a motivating experience.	0.03	50.1	0.5
3	*I am enthusiastic about teaching mathematics.	0.09	50.4	0.5

18	If mathematics was one of several college tasks to be completed at much the same time then generally I would attend to mathematics first.	0.16 0.16	50.7 50.7	0.5 0.5
22	At the end of my College course I intend to keep up with developments in mathematics education.	0.16	50.7	0.5
7	I want to find out as much as I can about mathematics.	0.33	51.5	0.5
25	*There has been enjoyment for me in recent mathematics experiences.	0.33	51.5	0.5
6	I want to read many articles and readings which are related to mathematics teaching.	0.34	52.0	0.5
4	*I have confidence to teach mathematics in the upper primary school.	0.49	52.4	0.5
8	*Mathematics is easy to understand.	0.56	52.5	0.5
23	I want to voluntarily attend extra courses in mathematics designed to improve my teaching competence.	0.67	53.0	0.5
20	*Mathematics is more important than most other subjects for primary pupils.	0.68	53.1	0.5
10	I intend to subscribe to journals concerned with mathematics teaching.	0.85	53.9	0.5
28	If a mathematics club for primary pupils was established in my school then I would participate.	0.97	54.5	0.5
26	Mathematics is one of my most preferred subjects.	1.06	54.8	0.5
21	*I am confident about undertaking electives in mathematics content.	1.23	55.6	0.5

*These items have been changed into positive form.

APPENDIX C

MATHEMATICS COMPREHENSION TEST AND ANSWER SHEET

Note to students: On your answer sheet circle the letter which best describes the answer you wish to make to the question.

Time limit: 45 minutes.

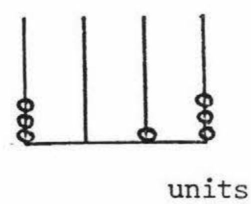
1. The number 2306 can be written in the form:

   (a) 200 + 30 + 6
   (b) 2000 + 30 + 6
   (c) 2000 + 300 + 6
   (d) 2300 + 6
   (e) none of these

2. The expanded numeral $4 \times 10^4 + 3 \times 10^2 + 4 \times 10^1$ represents the number:

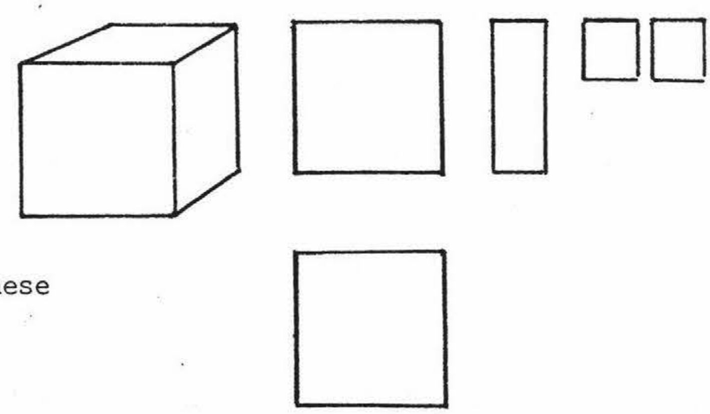
   (a) 4340
   (b) 43100
   (c) 43040
   (e) 40340
   (e) none of these

3. The number represented on the base ten abacus can be written:



   (a) 300 + 10 + 3
   (b) $3 \times 10^2 + 1 \times 10 + 3$
   (c) $3 \times 10^3 + 1 \times 10^2 + 3$
   (d) $3 \times 10^3 + 1 \times 10^1 + 3 \times 1$
   (e) none of these

4. The Multibase Arithmetic Blocks represent numbers in decimal notation. If the "long" represents the number 1, what number is then represented by the following arrangement?



   (a) 1212
   (b) 10212
   (c) 121.02
   (d) 121.2
   (e) none of these

5. The expanded numeral $5 \times 10^4 + 2 \times 10^2 + 3 \times 10^0$ represents the number:

   (a) 5230
   (b) 50230
   (c) 5023
   (d) 5203
   (e) 50203

6. The numeral 42.03 can be written in the expanded form:

   (a) $4 \times 10 + 2 \times 1 + 3 \times \frac{1}{10}$
   (b) $4 \times 10 + 2 \times 1 + 3 \times \frac{1}{1000}$
   (c) $4 \times 10 + 2 \times 1 + 3 \times \frac{1}{100}$
   (d) $4 \times 100 + 2 \times 1 + 3 \times \frac{1}{10}$
   (e) none of these

7. The expansion $3 \times 10^2 + 2 \times 10^1 + 3 \times 10^{-1}$ represents the number:

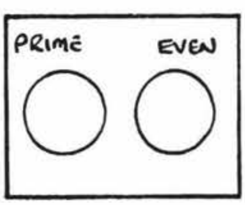
   (a) 323
   (b) 3023
   (c) 32.3
   (d) 320.3
   (e) none of these

Factors and Primes

8. What is the prime factorization of 36?

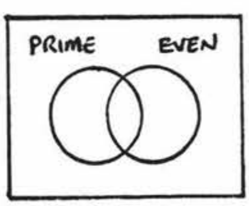
   (a) 9 x 4
   (b) 36 x 1
   (c) 2 x 3 x 6
   (d) 2 x 2 x 3 x 3
   (e) 2 x 3 x 3 x 3

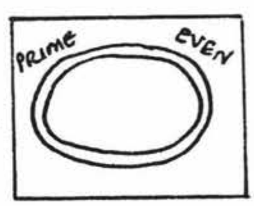
9. Which diagram best illustrates the relationship between the set of prime numbers and the set of even numbers?

(a)


(b)


(c)

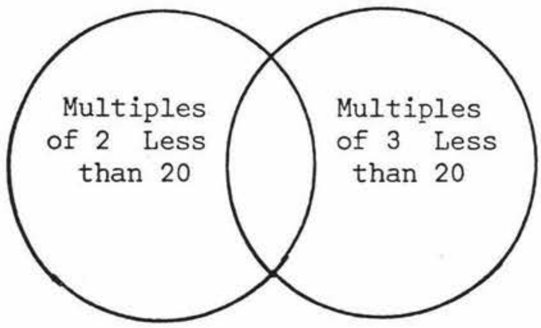

(d)


(e)


10. What is the greatest common factor of 18 and 54?

(a) 3
(b) 6
(c) 9
(d) 18
(e) 54

11.



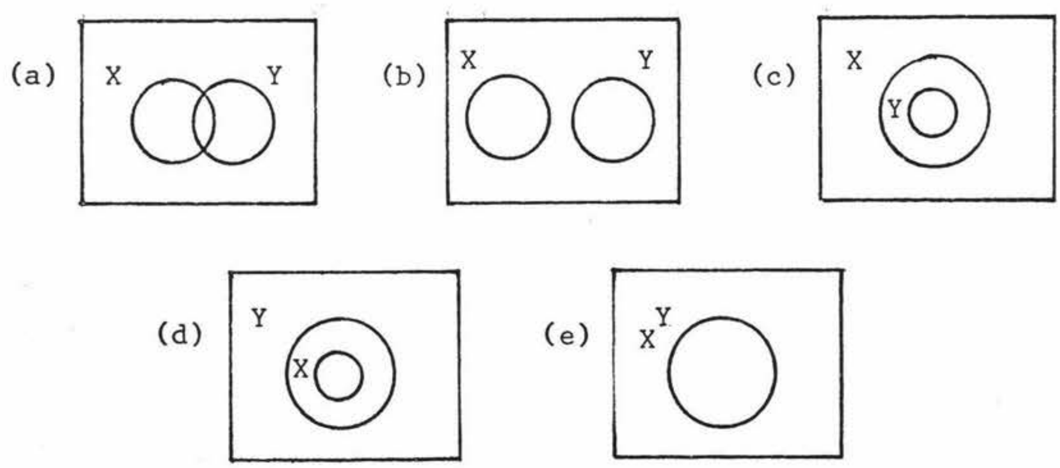
The numbers to be found in the central region are:

(a) 1
(b) 2, 3
(c) 6, 12, 18
(d) 4, 8, 12, 16, 6, 9, 15, 18
(e) 0

12. Which diagram best illustrates the relationships between the two sets of numbers?

X The set of square numbers greater than 1 but less than 20

Y The set of triangular numbers greater than 1 but less than 20



13. Which of the following is NOT a true statement?

(a) The sum of 2 consecutive triangular numbers is a square number.

(b) Every even number greater than 4 can be expressed as the sum of two odd prime numbers.

(c) Any prime number can be expressed as a product of only itself and one.

(d) A number is divisible by 9 when the sum of its digits is divisible by nine.

(e) Subtraction is commutative.

14. Study the pattern:

$$1^2 = 1$$
$$2^2 = 1^2 + 2 \times 1 + 1$$
$$3^2 = 2^2 + 2 \times 2 + 1$$
$$4^2 = 3^2 + 2 \times 3 + 1$$

From this pattern, 10^2 would be written as:

(a) $4^2 + 2 \times 9 + 1$

(b) $10^2 + 2 \times 10 + 1$

(c) $9^2 + 2 \times 9 + 1$

(d) $9^2 + 2 \times 10 + 1$

(e) $9^2 + 2 \times 9 + 9$

Base

15. The first eight natural numbers in the Zobs numeration system are 1, 2, 3, 10, 11, 12, 13, 20.

Which of the following base ten numerals names the same number as 23_{zob}?

(a) 9
(b) 10
(c) 11
(d) 12
(e) 13

16. If 22 is the product of 3 x 4 then the base being used is base:

(a) eight
(b) seven
(c) six
(d) five
(e) four

17. In a special numeration system 23 is written as **000 and 32 is written ***00. How would 4 be written in this system?

(a) **00
(b) ****
(c) 0000
(d) 00**
(e) none of these

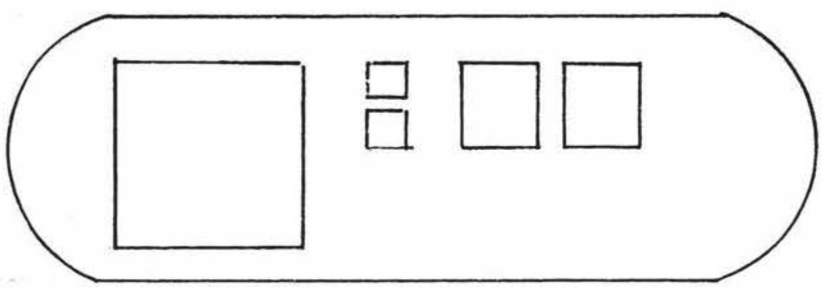
18. The base eight number 43eight may be written as:

(a) (3 x 8) + 4
(b) (3 + 8) x 4
(c) (4 + 8) x 3
(d) (4 x 8) + 3
(e) none of these.

19. In the base four system of numeration the number seventeen would be recorded as:

(a) 17
(b) 110
(c) 101
(d) 110
(e) none of these

20.



This arrangement of base four multibase material would be recorded in the following manner:

(a) 12_{four}
(b) 120_{four}
(c) 1002_{four}
(d) 102_{four}
(e) none of these

Clock Arithmetic

21.

Table A

X	0	1	2	3
0	0	1	2	3
1	1	.	.	.
2	2	.	0	.
3	3	.	X	.

Table A is to show a record clock 4 "addition" facts. The element in position X will be written as:

(a) 1
(b) 2
(c) 3
(d) 0
(e) 5

22.

Table B

X	0	1	2	3
0	0	0	0	0
1	0	1	2	3
2	0	2	0	2
3	0	3	2	1

Table B shows a record of the clock 4 "multiplication" facts. The identity element for this system is named by:

(a) 0
(b) 1
(c) 2
(d) 3
(e) there is no identity element.

23.

Table C

○	a	b	c	d
a	a	b	c	d
b	b	c	d	a
c	c	d	a	b
d	d	a	b	c

Table C illustrates a finite mathematical system. The sentence

a ○ c = c ○ a

demonstrates that the operation ○ is:

(a) equal
(b) associative
(c) distributive
(d) commutative
(e) none of these

24. In the system shown in Table C, the inverse of element d is named by:

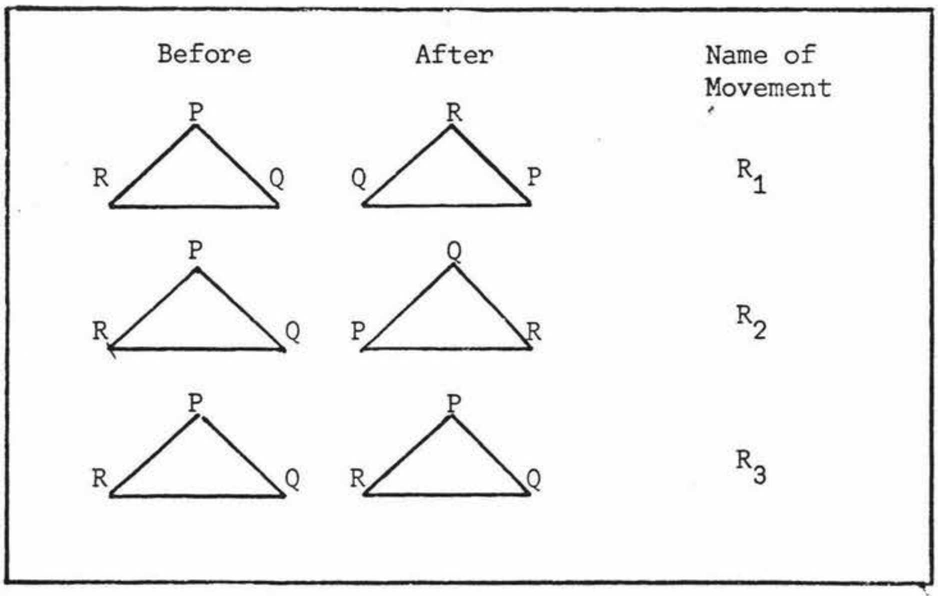
(a) a
(b) b
(c) c
(d) d
(e) none of these

25. Using the facts shown in Table C, the result of the operation b ○ c ○ d is given by:

(a) a
(b) b
(c) c
(d) d
(e) none of these

26. Three rotations are shown in the figure. They are described by a 1/3 turn, a 2/3 turn, and a full turn.

26. (cont.)



These movements can be illustrated as a mathematical system. Which table illustrates this system?

(a)

x	R_1	R_2	R_3
R_1	R_1	R_2	R_3
R_2	R_1	R_2	R_3
R_3	R_1	R_2	R_3

(b)

x	R_1	R_2	R_3
R_1	R_1	R_1	R_1
R_2	R_2	R_2	R_2
R_3	R_3	R_3	R_3

(c)

x	R_1	R_2	R_3
R_1	R_1	R_1	R_1
R_2	R_2	R_2	R_2
R_3	R_3	R_3	R_3

(d)

x	R_1	R_2	R_3
R_1	R_2	R_3	R_1
R_2	R_3	R_1	R_2
R_3	R_1	R_2	R_3

(e)

x	R_1	R_2	R_3
R_1	R_1	R_2	R_3
R_2	R_2	R_3	R_1
R_3	R_3	R_1	R_2

ANSWER SHEET

GROUP	IP [ ]	
SEX	M [ ]	F [ ]
STUDENTSHIP	DE [ ]	MA [ ]

1	2	3	4	5	6	7	8

1.	A	B	C	D	14.	A	B	C	D
2.	A	B	C	D	15.	A	B	C	D
3.	A	B	C	D	16.	A	B	C	D
4.	A	B	C	D	17.	A	B	C	D
5.	A	B	C	D	18.	A	B	C	D
6.	A	B	C	D	19.	A	B	C	D
7.	A	B	C	D	20.	A	B	C	D
8.	A	B	C	D	21.	A	B	C	D
9.	A	B	C	D	22.	A	B	C	D
10.	A	B	C	D	23.	A	B	C	D
11.	A	B	C	D	24.	A	B	C	D
12.	A	B	C	D	25.	A	B	C	D
13.	A	B	C	D	26.	A	B	C	D

APPENDIX D

THE STRUCTURE OF THE MATHEMATICS LEARNING CENTRE USED IN THE 'OPEN' METHOD OF INSTRUCTION

AREA OF STUDY 1 : NUMBER SETS

Topic A - Number Patterns

Activities Code	Activities Number	Reference	Materials Required	Method(s) of Instruction
A1	7	Judd (1975)	Hundred board	D/L*
A2	4	Nuffield (1970), Seymour (1970)		D/L/P
A3	8	Davison & Davison (1971)		D/L
A4	14	Seymour (1970) Nightingale (1972)		D/L/P
A5	5	Buckeye (1971)		D/L/P
A6	7	Buckeye (1971)	Cuisenaire Filmstrip	M/D

Topic B - Primes

B1,B2	14	Buckeye (1971) Davison & Davison (1971) Nuffield (1970)	Hundred board Counters Squared paper	D/L/P/M

Topic C - Factors

F1-15	15	Buckeye (1971) Nuffield (1970) Seymour (1970) Davison & Davison (1971)	Counters Cuisenaire rods Grid paper Film	D/L/P/M

Topic D - Figurate Numbers

B3	28	Nuffield (1970) Buckeye (1971)	Pegboard Dot paper Cubes Cuisenaire rods	D/L/P

AREA OF STUDY 2 : NUMERATION

Topic A - Place Value

Activities Code	Activities Number	Reference	Materials Required	Method(s) of Instruction
A1	5	Buckeye (1971)	Cuisenaire rods	D/P/L
A2	22	Dienes (1970)	Multibase Blocks	D/P/L
A3	21	Ruhen (1974)	Cuisenaire rods	D/M/L
A4	18	Ruhen (1975)	Multibase Blocks	D/P/L
A5	3	Davison & Davison (1971)	Counters	D/L

Topic B - Number Bases

B1	20	Davison & Davison (1972), Duncan	Counters	D/P/L
B2	12	Duncan	Cuisenaire rods	D/P/L
B3	9	Ruhen (1975)	Multibase Blocks	D/P/L
B4	5	Buckeye (1971)	Punched cards	D/P/M/L
B5	10		Filmstrips	M

AREA OF STUDY 3 : NUMBER SYSTEMS

Topic A - Clock Arithmetic

A1	6	Davison & Davison (1971)		P/D/L
A3	20	Nuffield (1970)	Counters	P/D/L
A6	6	Gardner (1966)	Geometric shapes	P/D/L

Topic B - Sets

A2	8	Davison & Davison (1971)	Attribute blocks	P/D/L

Topic C - Place Value

A4	10	Gardner (1966)	Abacus Multibase Blocks	P/D/L
A5	25	Gardner (1966) Duncan Dienes (197)	Abacus Multibase Blocks Counters	P/D/L
A9	5			M/D

Topic D - Systems

Activities Code	Number	Reference	Material Required	Method(s) of Instruction
A7	10	Gardner (1966)	People pieces	P/D/L
A8	6	Gardner (1966)	Geometric shapes	P/D/L

*Note: D = Discovery instruction

P = Programmed instruction

L = Lecture method of instruction

M = Media-assisted instruction (film, filmstrip, television)

APPENDIX E

ACTIVITY SEQUENCE GUIDE : MATHEMATICS LEARNING CENTRE

Notes to students:

(i) YOU are to elect your AREAS OF STUDY (preferably in areas of weakness or uncertainty).

(ii) THREE areas of study are provided - (a) Number sets, (b) Numeration, (c) Number systems.

(iii) YOU are to undertake at least one INTENSIVE study and one INTERMEDIATE study (variations can occur but only after consultation with a staff member).

(iv) Each area of study is divided into a number of activity topics. These are listed separately. Each is named with an alpha-numeric code.

(v) YOU are to register your studies with a staff member.

(vi) Separate booklets are to be used for each AREA OF STUDY.

AREAS OF STUDY

1. NUMBER SETS

Performance Levels:

Intensive - Two A levels plus one C level
Intermediate - One A level plus two B levels
Preliminary - One B level plus two C levels

Level	Topics			
	Number Patterns Activities	Primes Activities	Factors Activities	Figurate Activities
A	A1 or A2,A3,A4,A5,A6		F1-15 AT* articles	T1-28 + AT
B	A1 or A2,A3,A4,A5	B1,B2,B3	F1-12 AT articles	T1-18 + AT
C	A1,A2	B1,B2	F1,2,3,10,11,12	T1-6 + AT

2. NUMERATION

Performance Levels:

Intensive - One study to A level
Intermediate - Two studies to B level
Preliminary - One study to B level;
One study to C level

*AT, from Arithmetic Teacher.

Level	Topics: Place Value Activities	Topics: Number Bases Activities
A	A1 or A2,A3,A4,A5; part I,II or III	B1,B2 or B3,B4,B5
B	A1 or A2,A3,A4,A5; part II	B1,B3 or B2,B4,B5 A or B
C	A1,A2	B1,B3 or B2

3. NUMBER SYSTEMS

Performance Levels:

Intensive	-	Two studies to A level
Intermediate	-	One study to A level; Two studies to C level
Preliminary	-	One study to B level; Two studies to C level

Level	Topics: Clock Arithmetic Activities	Sets Activities	Place Value Activities	Number Systems Activities
A	A3 or A1,A6	A2		A7,A8,A9
B	A3,A1; 1 and 2		A4,A5,A9	A7(p.41),A9
C	A1; 1 and 2		A4(pp.8,9,10, 12,13) A5(pp.16-19)	

APPENDIX F

THE CONVENTIONAL MATHEMATICS PROGRAMME

AREA OF STUDY 1 : NUMBER SETS

Week		Topic	Mode of Instruction	Reference
1	(a)	The shape of numbers	Lecture	Bowie & Evans, 1968, pp.7-12, p.118 Schminke, Maertens & Arnold, 1973
	(b)	The shape of numbers	Tutorial	Bowie & Evans, 1968, p.120
2	(a)	Primes and composites, factors and multiples	Lecture	Byrne, 1966, p.142
	(b)	Primes and composites, factors and multiples	Tutorial	Byrne, 1966, p.142
3	(a)	Number patterns	Lecture	Nightingale, 1972, ch.11
	(b)	Number patterns	Tutorial	Nightingale, 1972, ch.11

AREA OF STUDY 2 : NUMERATION

Week		Topic	Mode of Instruction	Reference
4	(a)	Decimal system	Lecture	Byrne, 1966, ch.3
	(b)	Decimal system	Tutorial	Heddens, 1968, p.81
5	(a)	Other systems	Lecture	Schminke, Maertens & Arnold, 1973
	(b)	Other systems	Tutorial	Heddens, 1968, p.101
6	(a)	Characteristics of numeration systems	Lecture	Heddens, 1968, pp.117-124
	(b)	Characteristics of numeration systems	Tutorial	Heddens, 1968, p.125

AREA OF STUDY 3 : NUMBER SYSTEMS

Week		Topic	Mode of Instruction	Reference
7	(a)	Modulos arithmetic	Lecture	Gardner, 1966, ch.2
	(b)	Modulos arithmetic	Tutorial	Davison & Davison, 1972, p.45
8	(a)	Finite systems	Lecture	Gardner, 1966, ch.3
	(b)	Finite systems	Tutorial	Davison & Davison, 1972, p.51
9	(a)	Properties of finite systems	Lecture	Gardner, 1966, ch.3
	(b)	Properties	Tutorial	Davison & Davison, 1972, p.51
10	Post-test	Mathematics Comprehension		

APPENDIX G

THE PRESAGE AND PROCESS CHARACTERISTICS OF THE OPEN METHOD OF MATHEMATICS INSTRUCTION

A: Presage characteristics are the valued criteria which direct the organisation of a curriculum. These characteristics facilitate the occurrence of valued student behaviours within the interactive phase of instruction. The Presage characteristics of this study are as follows:

(1) Flexible scheduling of mathematics classes.

(2) A variety of instructional methods to be provided within each area of study.

(3) The students to be encouraged to use manipulative materials in their learning of mathematics.

(4) Individualised objectives for each student.

(5) The provision that students will have some choice in the following curriculum domains:

- (i) the mathematics content to be learned,
- (ii) the method of instruction to be experienced,
- (iii) the class period to be attended for mathematics instruction,
- (iv) the amount of time required for a student to complete selected areas of mathematics content.

(6) Individualised rates of learning.

B: Process characteristics of the open mathematics curriculum are valued behaviours that should occur during the active phase of instruction. These characteristics operationally distinguish between the conventional and open methods of instruction. The process characteristics desired in the open curriculum are shown below.

	Dimension	Process Characteristic
(1)	Target of instruction	The individual student
(2)	Student objectives	Flexible, varied, personalized, determined by the student and teacher

	Dimension	Process Characteristic
(3)	Furniture arrangement and space disposition	Moveable, flexible, variable, decided by the student and teacher.
(4)	Interaction between students and teacher	Initiated by teacher and students. Occurs between individuals and small groups
(5)	Student mobility	Fluid, unrestricted, wide range
(6)	Student progress	Irregular, differentiated, based on diagnosis
(7)	Classroom climate	Warm, supportive
(8)	Student evaluation	Individualised, personalised.

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