CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

DEVELOPING AN AUDIO CARD READER PROGRAM FOR
TEACHING SELECTED GEOMETRIC CONCEPTS

A project submitted in partial satisfaction of the
requirements for the degree of Master of Arts in
Education

by
Elinor W. Chilcote

June, 1974
The project of Elinor W. Chilcote is approved:

Committee Chairman

California State University, Northridge
June, 1974
Dedicated to

Dr. Vicki F. Sharp
Dr. Richard M. Sharp
Dr. John Schwartz
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ABSTRACT

DEVELOPING AN AUDIO CARD READER PROGRAM FOR
TEACHING SELECTED GEOMETRIC CONCEPTS

by
Elinor W. Chilcote
Master of Arts in Education
June, 1974

With the expansion of the elementary math program during the last decade, new teaching methods and materials were needed. Since geometry is one of the areas now taught at the elementary level, there arose a need for materials especially designed to present these concepts to children.

A sight and sound approach to learning was therefore explored, since it had proven to be successful in the teaching of reading.

A thorough research of the literature brought out the following conclusions: Math labs meet individual learner needs because they present a flexible environment in which real learning and understanding take place. Specific content must be geared to the ability of the child, and the use of concrete materials and audiovisual aids seem to promise a high degree of learning.
Against this background a unique method was developed for this project which consists of an audio card reader program. Thirty-two cards with a sound track along the bottom were designed to be inserted into an audio card machine at the student's own pace. The cards cover the following four areas: Points and lines, circles, angles and polygons. Each card presents a geometric concept in written, symbolic and abstract form. The cards were organized sequentially and were in learning centers which involve the students in discussing and learning together.

Each of the four sections contains a pre- and post-test related to the content of that section, and matches the written word to its correct geometric abstraction. A self checking system is built into each test which may also be adapted for teacher control. A table for accountability guidelines is also included.

A test was devised and validated to prove that in a controlled situation, significant learning took place in the group that used the audio card program whereas no significant learning took place with the other group. Thirty-eight sixth grade students were randomly selected for testing from a total sixth grade population in a 95 percent Spanish surname school. Nineteen students were involved in each group.

Since students involved in the audio card program achieved so well, this would indicate that the program would be a highly effective and motivational method of teaching these specific geometric concepts.

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CHAPTER I

INTRODUCTION

Background

Leading authorities in mathematics education have long felt the need for geometry to be taught at the elementary level. The California Statewide Mathematics Advisory Committee included it in their Strands Report, second edition, and textbook companies throughout the country now include geometry as a unit in mathematics. Prior to 1967 very little, if any, geometry was offered below the seventh grade. Today's elementary level students begin studying geometry in kindergarten and by the sixth grade they are into the concepts of points, curves, lines and rays, measuring planes, right angles, parallel lines, closed curves, circles, symmetry, number planes, area, intersecting planes, cylinders, cones, spheres, volume, data, bar graphs, and averages. This is a tremendous amount of material for a student to handle when eight other strands are also included in the total mathematics program.

Exploration of Effective Teaching Methods

Upon analysis of the content of the geometry program for grades four to six it appeared that certain concepts
could be taught using one of the multimedia approaches. The mathematical representations for the abstract ideas of points and lines led to developing this idea further. From these undefined terms, concepts such as ray, angle, circle and the parts of the circle, and so forth, are all built. The student learns these concepts from a textbook which presents the written word and the abstract form.

Since educators have long known that there is more learning taking place when more of the senses are involved, sound was the logical addition to be used for learning these concepts. This led to investigating the media for a sight and sound approach to learning.

The sight and sound approach was first introduced in 1967 by Bell and Howell. It offered a program called the audio card reader system which became a highly successful tool for learning to read. Since 1967 other companies have manufactured their own brands of readers and expanded the audio reader cards to include lessons in language arts, social studies, science, and some math. However, it is still called an audio card reader system. The available math material on this system is extremely limited and most of it is geared for primary levels. The research indicates that neither this media nor any other has presented these concepts using a sight and sound approach to learning.

This project developed thirty-two cards, a teacher's manual and tests in the area of geometry for use on an audio card reader system. The concepts were selected from the
material presented to and tested on students in grades four to six in textbooks that have been adopted across the country. They include basic concepts that provide the background for later lessons in geometry.

These specific concepts were also selected for their simplicity and their logical development. The four areas chosen appeared most likely to be successful on an audio card reader system.

Sample tests were developed to be used as a tool to determine the feasibility of using this media with this type of content. Revisions were made to improve the original tests where directions and/or other parts of the tests needed clarification.

The content covers four distinct concept areas: Points and Lines, Circles, Angles, and Polygons. The terms which appear on each card are as follows:

<table>
<thead>
<tr>
<th>Points and Lines</th>
<th>Circles</th>
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<tbody>
<tr>
<td>point</td>
<td>circle</td>
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<tr>
<td>point C</td>
<td>circumference</td>
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<tr>
<td>line</td>
<td>semicircle</td>
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<tr>
<td>line AB</td>
<td>arc</td>
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<td>line segment</td>
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<td>line segment AB</td>
<td>chord</td>
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<td>ray</td>
<td>diameter</td>
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<tr>
<td>ray RS</td>
<td></td>
</tr>
<tr>
<td>Angles</td>
<td>Polygons</td>
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<tr>
<td>angle</td>
<td>polygons</td>
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<tr>
<td>vertex</td>
<td>regular polygons</td>
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<tr>
<td>angle CDE</td>
<td>triangle</td>
</tr>
<tr>
<td>interior of an angle</td>
<td>right triangle</td>
</tr>
<tr>
<td>exterior of an angle</td>
<td>hypotenuse</td>
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<td></td>
<td>equilateral triangle</td>
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<td></td>
<td>similar triangles</td>
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<td>congruent triangles</td>
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<td>square</td>
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<td></td>
<td>rectangle</td>
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<tr>
<td></td>
<td>parallelogram</td>
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<td>trapezoid</td>
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CHAPTER II

REVIEW OF THE RELATED LITERATURE

Purpose of the Research

The purpose of this research was to determine the current content of geometry taught in grades four to six, the successful methods used for teaching it, the current trends in mathematics education and to determine if the material developed for this project, or anything similar, has ever been done before.

Research was conducted in the areas of geometry, mathematics, audiovisual aids, manipulative materials, math labs, math centers, in the fields of education and educational psychology, and in many of the methodology philosophies.

Addition of New Content Areas

The findings showed that there is much overlap in these topics. This is due to dramatic changes that have occurred in recent years in the teaching of mathematics. These changes have taken the form of including additional mathematical topics in the elementary school curriculum and in individualizing learning. Today's mathematics curriculum includes such topics as sets, logic, probability, applications, functions and graphs, and geometry as well as
the former topics of numbers and operations, measurements, and problem solving. The creation of the math lab and math centers, the introduction of manipulative materials and audiovisual aids at the elementary level, and the studies made on how children learn have made it possible to individualize instruction and present what was once considered advanced mathematics at an early age.

Swenson (1972) tells of how the change in the educational scene affected the revision of her text.

Since the first edition of this textbook was published in 1964, the educational scene in elementary mathematics has changed in certain ways which should be recognized in a text revision. Three major changes which must be considered are (1) the expansion of mathematics content in the elementary school curricula, (2) the improvement in mathematical background of the typical elementary school teacher, and (3) the current revival of interest in studies of how children learn.

One of the most obvious changes in the content of elementary school mathematics in recent years has been the marked expansion of the content in geometry. The texts and curriculum guides of a generation ago included little geometry except for work on measurement of length, area, volume, time and temperature, accompanied by tables of measure and word problems dealing with 'denominate numbers.' All that has changed.

A survey of the geometry content in recent elementary school mathematics texts and curriculum guides indicates that:

1. The number of geometry concepts presented and the amount of space devoted to them are more extensive than ever before.
Rationale for Expanded Content Areas in Math

Biggs and MacLean state causes that brought about these changes in mathematical content and feels that each child has the ability to learn them through individualized instruction.

With the changes in mathematical content brought about by new demands of industry and the business community, and in the increasing availability of the computer or computer time, mathematics promises to be an exciting subject with a wide appeal to many students.

Learning through individual and small-group investigations is applicable for all ages from kindergarten to postgraduate, and for all levels of ability from the slowest to the most able. This does not imply that all students must follow the same path. Some will require extensive experience with real materials whenever a new idea or concept is introduced; others need little.

The Association of Teachers of Mathematics (1967) state the importance of teaching mathematics at an early age and allowing children to have a wide range or variety of mathematical experiences.

The mathematical experiences before the age of eleven, and the responses he has been encouraged to make to them, largely determine his potential mathematical development. It is no longer possible to believe that the learning of mathematics properly begins in the secondary school, and that the only essential preparation for this stage is a certain minimum of computational skill in arithmetic. The learning of mathematics, in the widest sense, begins before the child goes to school and continues throughout the primary school and beyond, except when impoverished experience and unimaginative teaching stop development. We have written this book at a time when an increasing number of teachers accept this viewpoint and when changes are taking place in the mathematics taught in primary schools.
We strongly support all those changes which are designed to enrich the mathematical experiences of young children, and which emphasize the central importance of their activity and their ways of thinking.

Mathematics is now applied to a very wide range of situations and is not confined, as it once was, to the mechanics of the physical world. Completely new fields of mathematical applications have sprung up, some only a few years old. Operational research and cybernetics, to choose just two examples, are applications of mathematics to problems which formerly would not have been thought susceptible to mathematical analysis. Much of this work may seem a long way from the classroom and particularly from the primary school classroom. But its significance for the teacher lies in its demonstration of the vast number of things that are worth thinking about in a mathematical way. Mathematics is not just about number and space; it can be said to happen whenever the mind classifies and creates structures. This increases tremendously the range of experiences which turn out to be mathematically relevant, and it makes it easier for the teacher to create occasions for his pupils to use mathematics, and find situations which release mathematical thinking. One practical consequence of this is that, in the classroom, mathematics becomes more varied and therefore more enjoyable. Another is that the child can explore situations which are within his experience, which yield quite profound mathematics, and yet which do not require the technical equipment of memorized relationships and algorithms that traditional number work so often does.

Introduction of the Math Lab
Provided Individualized Instruction

Underhill (1970) in his support of individualizing instruction feels the math lab approach makes mathematics learning more fun and meaningful for children and states his reasoning.
Children deserve to be treated as unique individuals with special strengths and weaknesses.

All programs and procedures which claim to individualize instruction of mathematics seek to meet particular learner needs.

The laboratory movement has at its grass roots the intention of making mathematics learning exciting, interesting, and meaningful for children. Three of the main characteristics of this movement are (1) pupil-involvement in the discovery of mathematical relations and properties, (2) use of many manipulative aids, and (3) exploration of mathematical applications.

There is no single way to individualize instruction. Variety is the spice of life. Children learn best in an environment which is flexible and interesting in the variety it provides.

In the classrooms of today the students are involved and active in their learning. Biggs and MacLean (1969) state the reasons they feel are important.

The aims of learning mathematics in this active creative way are:

1. to free students, however young or old, to think for themselves.
2. to provide opportunities for them to discover the order, pattern and relations which are the very essence of mathematics, not only in the man-made world, but in the real world as well.
3. to train students in the necessary skills.

The major difference between a traditional program and a program which includes some active learning situations is the shift from mainly
an authoritarian, teacher-dominated classroom, to a child-centered one; from a program emphasizing content to one using the experiences of children to build concepts and strategies.

The Math Lab Setting

When asked, "What is a 'mathematics laboratory'"

Ewbank (1971) described the following.

A. The phrase is used to mean a place, a process, a procedure. As a place, it is a room set aside for mathematical experiments and practical activities. The term is also used for the type of approach use in a classroom whereby children work in an informal manner, move around, discuss, choose their materials and methods, and generally make and discover mathematics for themselves. This latter use of the term as a process and a procedure is far more important because not every school could have a mathematics laboratory but every school or individual teacher could use this method of teaching.

Barson (1971) lists the characteristics of a mathematics laboratory.

In general, a mathematics laboratory is activity-centered; the child is placed in a problem-solving situation and through self-exploration and discovery provides a solution based on his experience, needs, and interests. Described below are the similarities, or common bonds, that characterize many mathematics laboratories.

1. The room is organized with stations of activities where the children (individually, in small groups, or as an entire class) may work simultaneously on different materials or on the same materials at different rates.

2. The room is rich in materials, making use of commercial, teacher-made, and pupil-made devices.

3. The teacher works with small groups, with individuals, or with the entire class in a child-centered rather than teacher-dominated atmosphere.
4. The activities are usually open-ended to enable the students to extend their discoveries as far as they wish.

5. The organization of the laboratory work is flexible so that a child can move from one activity to another, depending on his interests and needs.

6. There is a multimedia or multisensory approach to learning, using tapes, films, concrete objects, records, listening centers, and so forth.

7. Textbooks and pamphlets are used as pupil reference materials. They are mostly ungraded and include a large variety of topics.

Copeland (1970) in discussing the classroom as a laboratory states:

Individualized instructional procedures should be part of the school program. . . . Carefully programmed and illustrated materials are necessary to provide sufficient aid for each individual pupil to proceed on his own or with his laboratory partner. The teacher then is free to move from child to child as help is needed.

The new emphasis on a math laboratory classroom situation for learning with free use of many materials is an important contribution to the nature of learning as envisioned by Piaget. . . .

The implications of Piaget's theories for mathematics education have not yet been realized. Studies by competent researchers involving American children are badly needed. New curricular materials, based on sound psychological evidence should be written. And, in teacher education, more work involving Piaget's theories and their implications would serve as landmarks in improving instruction in the elementary school.

Geometry Assumes Importance in the Elementary Curriculum

The area of geometry is an excellent example of a topic that was formerly only taught at the secondary level. Kennedy (1970) discusses this when he states:
Historically, geometry has been studied mainly after the completion of elementary school. Elementary schools were exposed to geometry only briefly; they learned to recognize some geometric shapes and become acquainted with formulas for determining areas and perimeters for simple plane figures. Today geometry has assumed a much more prominent role in the elementary school mathematics program. Through inductive, discovery-type lessons, children develop an intuitive understanding of some of its basic concepts.

Nonmetric geometry is included in the elementary school today because we now recognize that children can learn and use many geometric concepts, that its study encourages creativity and inquiry, and that it provides children with a break from the study of numbers and computation.

There is no agreement on what aspects of geometry should be taught in elementary school. Recommendations vary widely. Until further research, including classroom testing of teaching procedures, provides a more conclusive answer, teachers will have to use their own judgment.

Underhill (1972) describes the rising position geometry has obtained at the elementary level.

Curriculum evolves. During the past two decades 'modern math' has been incorporated into the elementary school mathematics curriculum. The curriculum is not stagnant. It continues to change as it responds to pressures and needs of learners, mathematicians, and society. Geometry is in a state of flux; it is evolving into a new, more dominate position in the elementary school curriculum. Analysis of trends in geometry provides an excellent opportunity to observe the evolutionary nature of curriculum.

The nature of the learner and the influence of mathematicians have been strong in the determination of geometric concepts in the curriculum since the late fifties and early sixties. Geometry was formally reserved for high school at which time concepts of Euclidean geometry were formally and extensively explored. Now the number and variety of geometric experiences for youngsters has increased considerably.
He acknowledges that although there is little agreement as to the exact nature and extent of geometry experiences for children, the influence of Bruner and Piaget has given strength to certain points of view relative to content and methodology.

He also agrees with Maredock (1970) and Vigilante (1967) that there are several reasons for introducing many geometric concepts into the elementary school curriculum and lists the following.

1. Students can gain a better understanding of their environment; they can see position, shape, and size in space as something they can understand, use, control, and manipulate to explore their environment.

2. Geometry strengthens the arithmetic program models for the arithmetic processes, so it can help children develop other mathematical insights.

3. In a practical sense, children can explore applications and learn that geometry is useful.

4. Children can learn to appreciate the aesthetic qualities of geometry.

5. Study of geometric concepts can help children grasp concepts of measurement.

6. Children can see a closer relation between mathematics and science.

7. Early study of geometry will enable children to acquire insights and will promote and develop creativity and inquiry.

All of the research completed for this paper indicates a unanimous acceptance of the concept of teaching geometry at the elementary level. Copeland (1970), however, has strong feelings about the levels at which some of the
concepts should be taught. Points and lines, he feels, should not be taught before the child is eleven or twelve years of age (or in the sixth/seventh grades), and supports his thinking by the conclusions he states are made by Piaget.

Since mathematics is a deductive science based on logical reasoning, there has been a tendency by elementary school textbook writers trained in mathematics to present mathematical ideas to children at an intellectual or logical level. Thus, in geometry the beginning is often a treatment of Euclidean ideas such as distance, length, angles, lines, triangles, and squares as they were "real elements" in space when, in fact, they often are not for young children.

The present practice in the primary grades of teaching that geometric ideas (lines, triangles, squares, etc.) are sets of points and should be re-examined. The smallest line to many children is a line segment, not a point. As to the concept of how many points or line segments there are in a line, the necessary drawing together of the topological relations of proximity, order, separation, and surrounding to form that of "continuity" (which allows the consideration of unlimited or infinite) is not developed in children until eleven or twelve years of age.

If Piaget is correct, it is a purely rote exercise to talk of lines as sets of points in the primary grades. In so doing the new math becomes as rote as the old math. Children begin to parrot definitions for rays, line segments, triangles, etc. They are not ready for such concepts. Logically space can be considered in terms of sets of points, so can lines and rays, but not psychologically before eleven to twelve years of age.

The environment and the materials do not permit a child to stagnate on any one level. Careful selection on the teacher's part will insure that he is given the concepts appropriate to his ability. Thus giving him a
readiness background for the next level of learning.

Crowder and Wheeler (1972) feel that readiness is too often associated with only the first grade and that it belongs in the teaching of all concepts at all levels.

"Readiness" is a word we usually—and erroneously—associate with the first grade. In mathematics there must be readiness at every level for each new concept. Some children will undertake one type of mathematics more readily than another. There is a lot of theory that boys have greater readiness for geometry than girls because they have usually played with more blocks and building materials and have taken apart more toys than have little girls. Whether or not this is true, we do not leave the child at his present state of readiness. We set up the environment and learning situations so that he learns new concepts each day, works with new materials, and thus attains readiness for new concepts.

Crowder and Wheeler (1972) talk of the advantages of teaching point, line, curves, and space, but do not indicate the level at which these are taught.

The teaching of geometry has earned a place in the elementary school mathematics program. Research has provided much evidence that children who have studied the ideas of point, line, curves, planes and space have a better perception of their physical environment than children who have not had this opportunity. Children are often highly motivated by the study of geometry.

Dodwell (1971) finds that too few studies have been done in the area of geometry and feels this topic has been strongly neglected.

... There is no extensive literature in the Piagetian tradition on geometry and spacial concepts to review, no hotly debated issues at either the theoretical or the experimental level on which to make judgements. To a remarkable degree this field has been neglected in the flood of experimental analysis on cognitive development of recent years.
Swenson (1972) refers to, among other topics, the addition of geometry in the revision of her text and lists in the chapter on geometry the topics given for the "teacher's overview." Here again, there are no grade levels indicated.

The expansion of mathematics content for the elementary school is recognized in the revision by the addition of sections on such topics as elementary geometry.

**Geometry Concepts**
- Points and Lines in Space
- Intersection and Union of Sets of Points
- Points, Lines, and Curves in a Plane
- Angles
- Polygons
  - Triangles
  - Quadrilaterals
- Circles
- Congruence, Symmetry, and Similarity
- Convex and Concave Figures
- Space Figures

Underhill (1970) refers to the studies by Bruner in which he says that a child is always ready for a concept in some way.

Bruner's famous pronouncement captures his attitudes relative to readiness. He feels that a child is always ready for a concept in some manner. When children are not ready for an abstract treatment, means can be found by which they can begin to develop an intuitive notion of the concept or to deal with it in mental imagery.

'The "curriculum revolution" has made it plain even after only a decade that the idea of "readiness" is a mischievous half-truth. It is a half-truth largely because it turns out that one teaches readiness or provides opportunities for its nurture, one does not simply wait for it. Readiness, in these terms, consists of mastery of those simpler skills that permit one to reach higher skills. . . .'
Irvin Vance (1973) lists criteria for selecting geometric topics in the elementary school and feels that some topics are appropriate for all grade levels in some form.

Geometric topics in the elementary school should be selected because they are good vehicles for the activity-oriented approach and meet one or more of the criteria listed below.

1. A topic that enhances the arithmetic and other areas of the mathematics program.

2. A topic that can be used to emphasize the inductive aspect of mathematics.

3. A topic that can aid in developing a spirit of inquiry.

4. A topic that adheres to a model which the student can easily make or use if provided.

5. A topic that is a good vehicle for teaching simple proofs (convincing arguments, counter-samples, miniproofs).

6. A topic that provides simple, profound, useful, or even pretty results.

7. A topic that is part of the continuum of mathematics topics for the elementary and secondary school.

The geometry program should include work on the line, the plane, and in space. . . . A topic may be included at all grade levels with an extended development of the topic at each level, or different aspects of the topic may be studied at each level. In addition, a topic may be studied at different levels with a different approach to the same result. The important thing is the integration of geometry with other entities in the mathematics program. There is no one program for geometry in the elementary schools but there are many topics from which to choose.
Manipulative Material and Audiovisual Aids Enter the Classroom

Willeford (1972) studied a survey which showed the increased emphasis on geometry at the elementary level. He also studied additional research that indicated the value of using manipulative materials. His report states:

A survey of text materials reveals that in the upper elementary grades use of manipulative materials has increased greatly since the turn of the century. Furthermore, students exposed to modern programs appear to learn more geometry than those students in the more traditional programs. . . .

Other research concluded that the use of a large amount of concrete materials was better than a moderate or a minimum amount in the middle elementary grades.

This leads the reader to infer that Willeford interprets a modern program as one in which concrete materials are used.

Studies and field tests have shown that students improve in all areas of mathematics when given manipulative materials, including audiovisual aids. Leading educators are encouraging math labs, study centers, individualized instruction, and open structure classrooms. College methods classes are training new teachers in this approach to learning mathematics. In California the State Legislated Miller Math Improvement Program trained teachers throughout the state in this method. This program affected 300,000 students during the three years it was in operation, 1969, 1970, and 1971. Test results showed students had a better understanding of mathematics and attitudes indicated a greater
appreciation and enjoyment of mathematics.

Madison Project, which preceded the Miller Math Improvement Program, was developed by Dr. Robert Davis as a means to reach the slow learner and underachiever. He used a discovery approach to learning, incorporating concrete materials whenever possible. The program met with such success that it became nationally funded. These funds provided the means to train groups of teachers throughout the nation. Dr. Davis patterned his program after the British Infant Schools, which had been, and still is, in successful operation in England. They used the open-structure approach which provided discovery learning experiences in a laboratory setting. They follow the philosophy of the Chinese Proverb which says,

I hear . . . and I forget
I see . . . and I remember
I do . . . and I understand.

Miller Math, Madison Project and many, many other programs that use the "I do" approach are carried on in today's classrooms.

Books and articles in the current issues of the publications relating to the fields of mathematics and education appear with titles such as Math Laboratories, How to Set Up a Math Lab, Open Structure Education, Freedom to Learn, Using Manipulative Materials in the Classroom, Considerations For Teachers Using Manipulative Materials, and so forth. In addition, the December, 1971 issue of the
Arithmetic Teacher is devoted entirely to mathematics laboratories.

Mathematics' conferences at the national, state, and local levels have been holding workshops on the use of manipulative and audiovisual materials for over five years. Geometry is always a well covered topic at both the workshops and the section meetings.

The quantity and variety of materials produced for classroom use is stupendous. This is in addition to the teacher-made and student-made materials. A great percentage of these materials were developed for use in mathematics learning. One company alone, Creative Publications, put out a ninety-three page catalogue on mathematics curriculum materials in 1973 with the announcement that the 1974 catalogue will be much larger. Many of the items listed in this catalogue and in many others are designed for use in the area of geometry.

The Need for the Audio Card Program

It is interesting to note that the catalogues which list mathematics material do not contain any audio card reader programs. Many do, however, list other forms of audiovisual aids such as films, filmstrips, tapes, transparencies, and so forth.

A new article, published in the National Council of Teachers of Mathematics, entitled "Audiovisual materials in mathematics" contains eighty-five pages listing just
audiovisual material in mathematics. In the section on geometry 52 films are listed, 135 filmstrips, 16 loops, 4 pages of transparencies, and 1-3/4 pages of video-tapes. The audio card reader system is not listed in even this extensive bibliography.

A six page "annotated bibliography of programmed instruction in elementary mathematics" developed by Henry H. Walbesser and published in the Arithmetic Teacher, December, 1971, has nothing listed under the heading of geometry.

A survey taken to determine the numbers and kinds of math programs developed by the commercial companies of audio card reader programs showed that nothing has been marketed like the program presented for this project.

The results of the findings of the research show that involving students in using aids and materials results in successful learning, the idea developed for this project has not been done before, and that audio card readers have been proven successful. It has also shown that geometry is not only teachable at the elementary level but that students are having success. This is due to the introduction of math labs and materials for the lab or centers. These allow for a new approach to teaching, one which individualizes instruction.

Audio reader cards provide a media in which geometry can be made representational for individualized instruction. They would also satisfy the needs stressed by Swenson (1972).
Though "points," "lines," and "space" are usually undefined terms in geometry, their meanings can be derived from representations of them.

The importance of the teacher's example in using the vocabulary of geometry cannot be overestimated. Hearing objects or concepts called by their correct names is "practice" for the learner in that he becomes accustomed to the right vocabulary and models his own language after what he has heard.

An adult who takes care to use correct names for geometric shapes will soon hear the children using those same names: square, triangle, circle, prism, angle, or line segment. After all, the kindergarten or first grade child has hundreds of words in his vocabulary for which he was never given definitions. He learned their meanings in use: dog, house, mother, pencil, or street. He can do the same for terms in geometry if he hears them used correctly.

This is the principle of the audio card reader program. The other authors of the related literature referred to in this paper indicate there is a need for this kind of program. It, therefore, seems logical to assume that using an audio card reader for teaching concepts in geometry should prove highly successful.
CHAPTER III

DEVELOPMENT, CONSTRUCTION, AND USE OF THE AUDIO CARD
PROGRAM FOR SELECTED GEOMETRIC CONCEPTS

Presentation of the Audio Card Program

The need for expanding the math program at the elementary level resulted in developing a set of geometric concepts on thirty-two audio cards to be used on an audio card machine, which prior to this time had been used successfully in reading, but not in geometry.

A teacher's manual, and pre- and posttests, related to the audio cards, were also developed. This manual gives detailed instructions as to the use of the audio machine and the audio cards.

Description of Cards

The actual audio reader cards are 3-7/16" x 9". The cards reproduced on the following pages have been reduced in size to fit the page.

The original cards are in black and white, with the emphasis in red. Where the emphasis is needed in the reproduced cards dotted lines are used.
circumference

semi-circle

2b

semi-circle

2c
equilateral triangle

similar triangles

4f

4g
congruent triangles

square
The Audio Card Program for Teaching
Selected Geometric Concepts

Objectives:

To build a vocabulary of geometric terms.
To recognize and identify geometric figures.
To include the senses of sight and sound in the learning process.
To individualize instruction.
To let the student determine his own rate of learning.

Content:

There are thirty-two audio cards to be used with an audio card reader system. The cards cover four distinct geometric areas.

1. Points and Lines
2. Circles
3. Angles
4. Polygons.

The cards are nongraded and designed for students working on fourth to sixth grade levels.

Each card contains a geometric concept in written form, symbolic form when applicable, and in the abstract form. The verbal name for that concept is recorded on a magnetic tape along the bottom of each card.
For each of the four areas covered on the cards, a test is included which may be used as a pre- or posttest or both with an optional self-checking answer section. Suggested accountability guidelines are given for each test.

Method:

**Self Teaching**

Simultaneous sight and sound learning takes place. The student feeds a card into an audio reader machine. The card slides across the student's vision allowing him to see the geometric concept in written form, symbolic form when applicable, and in the illustrated or abstract form, while at the same time hearing the verbal form. He then enters the next card into the machine.

**Individualized Instruction**

This media is designed for a one to one relationship. One student may have the complete use of one machine for the time he needs to use it.

**Teacher Managed and Prescribed**

The teacher determines the concepts the student needs to learn and organizes the time schedules allocated for the learning.
The Buddy System

Pilot tests show that the retention span is lengthened when two pupils, at relatively the same levels of learning, work together taking turns feeding cards into the machine. Discussions such as "Let's see if I can remember," or "Let's see if we can do this one," tend to evolve.

Sequential Organization

The concepts on the cards are presented in a suggested sequential order in each area. The numbering system of 1a, 1b, 1c, 2a, 2b, 2c, and so forth, is used.

Learning Centers

Four learning centers can be set up, each utilizing the concepts in one of the geometric areas. Each area is independent of knowledge acquired from the other. A classroom with four machines can accommodate four to eight students at a time, depending upon if you prefer to use the Buddy System. The number of machines and audio card reader systems available determines the number of students involved at any given time.

Student Involvement

The student becomes involved with his own learning progress. The program is self-pacing.
Reinforcement

The student may reenter the card as often as he needs in order to grasp the concept.

Self Checking

The cards have a chip which can cover up the visual, written, and symbolic portion of the card. The student can enter the card, press a button that allows him to verbalize the concept, instead of hearing it from the machine, and then reenter the card and check if his verbalization was correct.

Testing for Accountability:

The evaluation and testing program includes thirty-two items. There are eight tests, four pretests and four posttests, which contain the content covered in the four areas. The tests are numbered to correlate with the numbering system on the cards and each test comes in two versions labeled A and B. Either version may be given for the pre- or posttested. The two versions allows a teacher to give different pre- and posttests.

The test asks the student to match a written word to the correct geometric abstraction of that word. The answers are given below a dotted line which appears near the bottom of the page. The student can fold back that part of his paper, take the test, then open his paper and check his work or the teacher may want
to tear off that section and correct the test herself.

As pre- and posttests the following table has been set up as suggested accountability guidelines. Numbers given refer to the number of correct answers. Unteachable means that his background is not sufficient enough for him to grasp the concepts presented on the cards in that area. Teachable means that he is ready and can learn this material, and mastery means that he already has a strong background in this area and is ready to go on to something else.

<table>
<thead>
<tr>
<th></th>
<th>Unteachable</th>
<th>Teachable</th>
<th>Mastery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests 1A &amp; 1B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points &amp; Lines</td>
<td>3 or less</td>
<td>4-6</td>
<td>7 or more</td>
</tr>
<tr>
<td>Tests 2A &amp; 2B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circles</td>
<td>3 or less</td>
<td>4-5</td>
<td>6 or more</td>
</tr>
<tr>
<td>Tests 3A &amp; 3B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angles</td>
<td>2 or less</td>
<td>3</td>
<td>4 or more</td>
</tr>
<tr>
<td>Tests 4A &amp; 4B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polygons</td>
<td>5 or less</td>
<td>6-9</td>
<td>10 or more</td>
</tr>
</tbody>
</table>
Select the best illustration for each of the terms listed below.

1. Line segment
2. Point C
3. Ray RS
4. Line
5. Point
6. Line segment AB
7. Ray

ANSWERS

1. f
2. c
3. h
4. b
5. e
6. a
7. d
8. g
PART 1B: POINTS AND LINES

Select the best term for each of the illustrations shown below.

1. \[\text{---}\]
2. \(C\)
3. 
4. \(\text{A} \rightarrow \text{B}\)
5. \(A \rightarrow B\)
6. \(R \rightarrow S\)
7. 
8. 

\[\begin{array}{ll}
a. & \text{Ray RS} \\
b. & \text{Point C} \\
c. & \text{Line segment} \\
d. & \text{Line} \\
e. & \text{Point} \\
f. & \text{Ray} \\
g. & \text{Line segment AB} \\
h. & \text{Line AB} \\
\end{array}\]

ANSWERS

\[\begin{array}{cccc}
6 & a & 7 & c \\
2 & b & 1 & d \\
3 & e & 5 & g \\
8 & f & 4 & h \\
\end{array}\]
PART 1B: POINTS AND LINES

Select the best term for each of the illustrations shown below.

1. __ a. Ray

2. __ b. Point C

3. __ c. Line segment

4. __ d. Line

5. __ e. Point

6. __ f. Ray

7. __ g. Line segment AB

8. __ h. Line AB

ANSWERS

6 a. ______

7 c. ______

3 e. ______

5 g. ______

2 b. ______

1 d. ______

8 f. ______

4 h. ______
PART 2A: CIRCLES

Select the best term for each of the illustrations shown below. The dotted areas indicate the parts described.

1.  

2.  

3.  

4.  

5.  

6.  

7.  

___ a. Circumference  

___ b. Chord  

___ c. Semi-circle  

___ d. Radius  

___ e. Arc  

___ f. Diameter  

___ g. Circle

ANSWERS

2 a.  

3 c.  

4 e.  

1 g.  

6 b.  

5 d.  

7 f.
PART 2B: CIRCLES

Select the best illustration for each of the terms listed below. The dotted areas indicate the parts described.

1. Chord  5. Circumference
2. Diameter  6. Radius
3. Circle  7. Radius
4. Arc

ANSWERS

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</tbody>
</table>

ANSWERS

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<td></td>
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<td>g</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
PART 3A: ANGLES

Select the best illustration for each of the terms listed below. The dotted areas indicate the parts described.

___ 1. Angle CDE  ___ 4. Vertex
___ 2. Exterior of an angle  ___ 5. Interior of an angle
___ 3. Angle

a.  

b.  

c.  

d.  

e.  

--- ANSWERS ---

_ c 1. _ a 3. _ d 5. 
_ e 2. _ b 4. 

---
PART 3B: ANGLES

Select the best term for each of the illustrations shown below. The dotted areas indicate the parts described.

1. 2. 3. 4. 5.


ANSWERS

4 a.  1 b.  3 c.  5 d.  2 e.
PART 4A: POLYGONS

Select the best term for each of the illustrations shown below. The dotted areas indicate the parts described.

1. △ △ △  
2. □  
3.  
4.  
5.  
6. △  
7. △ △  
8.  
9. □  
10.  
11. □  
12. △ △

___ a. Similar triangles  ___ g. Congruent triangles
___ b. Polygons  ___ h. Regular polygons
___ c. Parallelogram  ___ i. Right triangle
___ d. Triangle  ___ j. Rectangle
___ e. Trapezoid  ___ k. Square
___ f. Hypotenuse  ___ l. Equilateral triangle

ANSWERS:

7  a.  
1  b.  
10  c.  
3  d.  
12  e.  
2  h.  
5  f.  
8  g.  
4  i.  
11  j.  
9  k.  
6  l.
PART 4B: POLYGONS

Select the best illustration for each of the terms listed below.

1. Square
2. Polygons
3. Right triangle
4. Trapezoid
5. Regular polygons
6. Rectangle
7. Congruent triangles
8. Hypotenuse
9. Equilateral triangle
10. Similar triangles
11. Parallelogram
12. Triangle

ANSWERS

1. c
2. e
3. a
4. i
5. j
6. k
7. h
8. g
9. f
10. l
11. d
CHAPTER IV

RESULTS

Subjects

The subjects in this project were 38 sixth grade students who were randomly assigned from a total sixth grade population of 165 in a 95 percent Spanish surname school.

Data Analysis

The t test was used twice to determine the statistical significance of the difference in mean scores achieved by the test validation group and by the audio card group.

The t test was used for the test validation group to indicate that no significant learning would take place as a result of using the geometry concepts test twice.

The results of the test validation group are presented in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>X</th>
<th>S.D.</th>
<th>t</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>19</td>
<td>2.79</td>
<td>1.15</td>
<td>1.59</td>
<td>(n.s.)</td>
</tr>
<tr>
<td>Posttest</td>
<td>19</td>
<td>3.37</td>
<td>1.31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*one-tailed
Results from Table 1 show that the students achieved no significant learning after retaking the geometry concepts test.

The $t$ test was also used for the audio card group to show that significant learning was achieved as a result of using the audio card program.

Table 2
Audio Card Results

<table>
<thead>
<tr>
<th></th>
<th>$N$</th>
<th>$\bar{X}$</th>
<th>S.D.</th>
<th>$t$</th>
<th>$p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>19</td>
<td>2.58</td>
<td>1.27</td>
<td>4.27</td>
<td>$p &lt; .01$</td>
</tr>
<tr>
<td>Posttest</td>
<td>19</td>
<td>26.89</td>
<td>5.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*one-tailed

Results of Table 2 show that the audio card group achieved significant learning on the geometry concept test.

The data showed that the audio card program was an effective learning tool. Furthermore, the geometry concepts test was a valid instrument.

Conclusions

This project demonstrated that the audio card geometry program was effective as a learning tool. The data from Table 2 supported this.

The geometry concepts test was considered a suitable instrument for this project.
CHAPTER V

FINDINGS, RECOMMENDATIONS, AND CONCLUSIONS

Findings

1. A long-felt need for expanding the math program at the elementary level, resulted in the inclusion of geometry in the California Strands report, as well as in the new math programs across the country.

2. The geometry concepts now taught at the elementary level, such as points, angles, intersecting planes, and so forth, were formerly not introduced until junior high school.

3. In order to handle this unfamiliar material most effectively, a new approach seemed to be needed.

4. To involve more senses in the learning process, sound appeared to be the logical addition. A sight and sound approach to learning was therefore explored. Although it had never been tried in the teaching of math, it had been proven successful in building reading skills.
5. Specifically, this geometry program involves the use of an audio card machine, cards illustrated with geometry concepts, teacher's manual, and pre- and posttests.

6. To determine the current math content taught at the elementary level and ways in which it is being presented.

7. Research showed that geometry is now included with other new content material, which necessitates new teaching methods.

8. New demands of industry and the community, and increasing availability of the computer, broadened the need for an expanded math program.

9. Educators became aware of the ability of younger children to understand math content formerly taught at a higher level.

10. Mathematics, as applied to a wider range of situations in the classroom as well as in the real world, gained a more important place in the curriculum.

11. Studies of how children learn, made it possible to introduce such subjects as geometry to children at a much younger age.

12. Math labs served to meet individual learner needs, and made the learning exciting, interesting, and meaningful for the children.
13. As students became involved and made their own discoveries, they began to think for themselves.

14. Real learning and understanding took place in an environment which was flexible and interesting because of the variety it provided.

15. The teacher-dominated traditional program was replaced by a child-centered one in which their own experiences were used to build concepts and strategies. Thus, the teacher was freed to circulate and help individual children as needed.

16. The physical set-up can be a series of math centers or stations of activity within a schoolroom. Centers vary in numbers according to the needs of the class.

17. Children work in an informal manner, move around, changing centers, and generally make and discover mathematics for themselves. Many open-ended activities are included.

18. The math lab is also thought of as a process, and a procedure and every school and teacher could use this as a method of teaching.

Recommendations

1. The study of geometry encourages inquiry and creativity and provides a relief from the rote learning of numbers and computation.
2. It also strengthens the whole arithmetic program as it develops in children other mathematical insights.

3. Much of the research, including that of Piaget and Brunner, cautions that the specific content be geared to the ability level of the child.

4. There must be readiness at every level for each new concept introduced to a child.

5. Use of concrete materials has increased greatly under the expanded math program.

6. Learning increased in relation to the amount of materials used with children.

7. British Infant Schools, Madison Project and Miller Math Improvement Program all emphasized the use of concrete materials in the learning process.

8. The understanding of geometry was enhanced by the use of manipulative materials and audio-visual aids.

9. Each center is provided with materials for learning which are varied and stimulating. These might include instructions, task cards, films, filmstrips, concrete objects, records, listening centers, and so forth. They may be teacher-made, pupil-made or commercial.
10. Textbooks, pamphlets, magazines and encyclopedias are provided and used as pupil reference materials. They are ungraded and include a wide variety of topics.

Conclusions

1. Since other audiovisual aids proved highly effective in this area, the use of this sight and sound method seemed to promise a high degree of learning.

2. These cards provide the child with illustrations of otherwise abstract geometric concepts. A point, line segment, and so on, has more meaning.

3. In addition to the visual representation, the geometric vocabulary word is seen and heard, whereby the learner builds a correct vocabulary of geometric terms.

4. Research showed that the audio card program has not been used as a multi-sensory tool in the teaching of geometry, and it should prove to be highly effective.
BIBLIOGRAPHY


Barson, Alan. The mathematics laboratory for the elementary and middle school. The Arithmetic Teacher, 1971, 18(8), 565-567.


Deno, Stanley L., Johnson, Paul E., & Jenkins, Joseph R.
Associative similarity of words and pictures.

Dienes, Zoltan P. Building Up Mathematics. London:
Hutchinson Educational, 1970.

Dodwell, Peter. Children's perception and their understand-
ing of geometrical ideas. Piagetian Cognitive-
Development Research and Mathematical Education.
Washington, D.C.: National Council of Teachers of

Duncan, Ernest R., Capps, Lelon R., Dolciani, Mary P.,
Quast, W. G., & Zweng, Mary. Modern School Mathe-
ematics Structure and Use. Grades 4, 5, 6. Boston:

Eicholtz, Robert E., O'Daffer, Phares G., & Fleenor, Charles
R. School Mathematics I and II. Menlo Park, Calif.:
Addison-Wesley Publishing Co., 1973

Eicholtz, Robert E., O'Daffer, Phares G., & Fleenor, Charles
R. Investigating School Mathematics--Grades 4, 5, 6.
Menlo Park, Calif.: Addison-Wesley Publishing Co.,

Eicholtz, Robert E., & O'Daffer, Phares G. Elementary
School Mathematics--Grades 4, 5, 6. Menlo Park,

Elliott, H. A., MacLean, J. R., & Jorden, Janet M.
Geometry in the Classroom. Toronto: Holt, Rinehart

Ewbank, William A. The mathematics laboratory: What? why:
when? how? The Arithmetic Teacher, 1971, 18(8),
559-564.

Flavell, John H. The Developmental Psychology of Jean

Geometry Committee of the Ontario Institute for Studies in
Education. Geometry: Kindergarten to Grade
Thirteen. Ontario: Ontario Institute for Studies

Gilpin, John. Design and evaluation of instructional sys-
tems. Audio Visual Communication Review, 1962, 10(2),
75-84.


Wardrop, R. F. Effect of geometric enrichment exercises on the attitudes toward mathematics of prospective elementary teachers. School Science and Math, 1972, 72, 794-800.


Williford, Harold. What does research say about geometry in the elementary school? The Arithmetic Teacher, 1972, 19(2), 97-103.

