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DEVELOPMENT OF A SELF-INSTRUCTIONAL SYSTEM
TO TEACH METRIC TEMPERATURE

BY

GEORGIA K. POSEY

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major
in Home Economics, South Dakota State University

1975

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DEVELOPMENT OF A SELF-INSTRUCTIONAL SYSTEM TO TEACH METRIC TEMPERATURE

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Thesis Adviser

Date

Dean, College of Home Economics

Date
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Chapter 1

INTRODUCTION

Change to the metric system is a threat to many people in the United States. This inevitable change has, however, the advantages of bringing measurements into conformity with the rest of the world and simplifying the measurement system.

The metric system is not new to Americans. Students of science have been exposed to metric measurements for many years, and it has become common to hear the terminology when getting prescriptions filled or watching the Olympics on television. Yet, there is a surge of panic to many homemakers when they realize that soon they will no longer buy butter by the pound or milk by the quart, measure room dimensions by the foot, and bake cakes at a familiar 350°F.

BACKGROUND FOR THE STUDY

Although many materials have already been developed to make the conversion to metric measurements easier, several problems may be cited. Unfortunately, many metric materials were merely conversion aids rather than real teaching materials offering experiences with metric measurements. Also, some excellent teaching materials for litres,
metres, and grams have ignored Celsius entirely. Materials developed for classroom use with active student involvement through hands-on experiences have been impractical for individualized home use. Also, not all available metric materials have gone through a cycle of testing and revision.

The systems approach that has become popular as a procedure for solving problems in business and industry has finally been adapted to education for use in developing instructional materials for maximum efficiency. Empirically developed materials to teach metric measurements would be proficiency oriented. Rather than originating from an idea of how to teach metric measurements, the instruction would originate from an evaluation of what a person needs to be able to do to show proficiency with metric measurements.

The instructional methods would be secondary to the desired outcomes or objectives, according to the systems approach.

OBJECTIVE OF THE STUDY

The objective of the study was to develop a self-instructional system for teaching one area of metric measurements, temperature. This system was to be individualized, enjoyable, inexpensive, suitable for home use as well as classroom use, and appropriate for use by homemakers and consumers rather than industry. In addition, the system was to be designed to teach students to the mastery level of learning.
The self-instructional system was geared to the tenth-grade level since tenth graders have not grown up using metric measurements. Furthermore, materials developed for tenth graders would be adaptable for adult instruction. All materials were developed for use by present or future homemakers of both sexes.

The problem was one of learning to "think metric" rather than to merely memorize complicated conversion formulas as students of science have often been taught. Teaching materials were developed to help the students to think and approximate metric measurements by learning reference points such as temperatures for the body, room, and the boiling and freezing of water. Conversions were estimates; where accuracy was required, the student was taught to use a conversion slide accurately.

Prerequisites to the system required that the student be able to read Fahrenheit thermometers accurately and use Fahrenheit measurements for expressing common temperatures such as room temperatures, outdoor temperatures, body temperatures, and the freezing and boiling temperatures of water. The teaching materials developed were aimed at mastery-level learning of the following five criterion objectives:

The student...

1. approximates the conversion of Fahrenheit to Celsius temperatures using the
formula \( C = F/2 \) for temperatures over boiling and the formula \( C = F/2 - 15 \) for temperatures under boiling.

2. approximates without the use of conversion instruments common Celsius temperatures such as room temperatures, outdoor temperatures, body temperatures, and the freezing and boiling temperatures of water.

3. explains that the range between two adjacent Celsius integers is larger than between two adjacent Fahrenheit degrees at the ratio of \( 5^\circ C = 9^\circ F \).

4. chooses among various temperature ranges the appropriate one for a thermometer having a specific use, such as an oven thermometer.

5. converts Fahrenheit temperatures to Celsius measurements and vice versa using a conversion slide.

PROCEDURE

Literature on the systems approach to developing instructional materials was reviewed. The learnings from this review of literature were then applied in developing individualized materials to teach Celsius temperature. Teaching instruments included a computer-printed self-instructional booklet, a booklet of visuals, three card games for enjoyable drill and review, and a conversion slide. Pre- and post-tests were used to evaluate the accomplishment of criterion objectives.

Before the system was reproduced for group testing, five subjects worked through the materials under the
researcher's observation, and revisions were made between each of the five trials. Field testing of the system in its final form involved over 100 subjects, including students and adults of both sexes with a variety of educational backgrounds. Mastery-level learning was arbitrarily set at 80 percent accuracy on the post-test. The goal of the research was to develop a program on which 80 percent of the subjects achieved the mastery level.

DEFINITIONS OF TERMS USED

The terms used in this writing apply to teaching metric measurements by the systems approach in education as they are understood and used by the author.

Conversion slide: a mechanical device that matches metric and English measurements of equal value on adjacent scales.

Criterion objectives: learner behaviors or observable performance tasks that are the desired outcomes of instruction.

Empirical development: the development of educational materials using feedback from subjects in a test-revision cycle.

Feedback line: a line, often dotted, on a flowchart illustrating a logical sequence for revision.

Flowchart: a pictorial representation of a process, such as the development of teaching materials, showing the steps and sequencing in a graphic manner.

Formative evaluation: an on-going judging of instructional materials to see how well they are working or have worked in helping students to meet objectives.
Higher-level objectives: objectives involving application, analysis, synthesis or evaluation in the hierarchy of educational objectives presented in the Taxonomy of Educational Objectives; Cognitive Domain, edited by B. S. Bloom.

Homemaker: a person, male or female, who manages a home.

Individual evaluation: an effort to determine how much knowledge one possesses or has gained from being exposed to instructional materials.

Instructional materials: a term used synonymously with teaching materials and teaching instruments.

Mastery-level learning: the attainment of a level of learning specified by the developer of the learning materials.

Metric measurements: a system of measurements of dimension, quantity, or capacity referred to as the International (Metric) System, which is based on the number "10."

Programmed instruction booklet: a sequence of carefully constructed items leading a student through a self-instructional set of teaching materials to the mastery of a subject with a minimum number of errors.

Self-instructional system: an empirically developed instructional package intended to be self-teaching, not requiring the help of a teacher.

System analyst: a person trained in selecting the most efficient and effective components of a system so that benefits are maximized at minimum resource cost.

System approach: a decision-making method for optimizing solutions to problems by defining the problem to be solved, examining potential solutions, selecting a solution, measuring the results, and revising the approach to best solve the problem.

Task analysis: a study of the constituents of performing some action.
Chapter 2

REVIEW OF LITERATURE

This chapter reviews recent literature on the systems approach, the decision-making process used to develop the instructional materials for teaching metric temperature. Although an effort was made to limit the review to the last five years, a few sources are included that date back to the early sixties.

Actual research studies on the systems approach are extremely limited. Attempts to evaluate a decision-making process tend to turn into evaluations of the products of the process rather than the process itself. Therefore, the emphasis of this chapter is to provide some background and explanation of the systems approach. First, the evolution of the approach will be presented, followed by a step-by-step explanation of the process. The chapter concludes with the systems approach's potential in developing instructional materials.

EVOlUTION OF THE SYSTEMS APPROACH

Change is inevitable. Whether it be government, business, or education, the efficiently operating system must change continuously to remain relevant. One's outlook on change can be active or passive. Kaufman (1972) felt
that if one acts to initiate change rather than just reacts to change, he becomes a "master" rather than a "victim" of change. The systems approach is an "active" attempt to meet the need for change.

Lehmann (1968) stated that there is nothing new about the systems approach; it is only a new look at the scientific method, a logical step-by-step approach often used, however unconsciously, to solve problems. The systems approach is the behavioral science's problem-solving method. Cassel (1969) dated the approach's origin to just before World War II when English scientists first developed radar and were seeking uses for it. At that time it was often referred to as "operational research."

Soon the process spread into the United States military, government, and industry. An effective decision-making process was crucial when a problem was of such magnitude that its improper solution could lead to excessive costs or disaster. The military was especially influential in early research in the area. According to Pfeiffer (1968, p. 140), "The really big push came with the White House Executive Order of 1965 which stipulated that all federal programs should be evaluated by modern planning-budgeting techniques. . . ."

Eisele (1973) stated that pressures for accountability in education have had a strong influence on the acceptance of the systems approach in education. Also, he
felt that instruction is finally being recognized as a truly complex task. For example, Pfeiffer (1968, p. 9) reported an estimate that "enough new information to fill a twenty-four volume set of the Encyclopedia Brittanica is added to the world's libraries every forty minutes. . . ." Root (1973, p. 35) supported this idea:

Our educational systems are so complex, with so many nonlinear, interconnected feedback loops, that the unaided human brain cannot cope with the simultaneous interactions. A technique must be adopted to represent these dynamic phenomena in a way that is helpful to practical decision-makers.

The systems approach is the technique that is being used to make educational decisions today.

EXPLANATION OF THE SYSTEMS APPROACH

Kaufman (1972, p. 1) described a system as the "sum total of parts working independently and working together to achieve required results or outcomes, based on needs." He felt that purpose and organization are essential to a system. Resnick (1972) also emphasized the interdependence of the parts and the idea of the whole being greater than the sum of the parts in a system. In his article "The Systems Approach to Programming" Kaufman (Ofiesh and Meierhenry, 1964, p. 33) carried it a step further:

Only when all components within a system can be identified and their contribution towards achieving mission objectives determined can it be said that a systems approach is being used.
The systems approach has done more, however, than identify the separate parts of a system, although this has been extremely important. Lehmann (1968, p. 144) called it "...a process which is structured to minimize prejudicial preconceived notions and maximizes the objectivity required to arrive at a scientifically correct answer." A little more specifically, Kaufman (1972, p. 2) defined the system approach as follows:

System approach: A process by which needs are identified, problems selected, requirements for problem solution identified, solutions are chosen from alternatives, methods and means are obtained and implemented, results are evaluated, and required revisions to all or part of the system are made so that the needs are eliminated.

These steps in the decision-making process vary slightly among systems-approach authors. Basically, however, they are the same. Lehmann (1968) listed the eight steps of the systems approach as need, objectives, constraints, alternatives, selection, implementation, evaluation, and modification. Resnick (1971, p. 156) divided the process into four steps: "1. Where are we now? 2. Where are we going? 3. How shall we get there? 4. How will we know when we've arrived?" Likewise, Pfeiffer (1968) saw the systems approach as having three steps: design for action, seeking alternatives, and evaluation. Baker (Travers, 1973) also saw the process in three steps: specification, field testing and revision. Any of these organizational patterns offers the decision-maker a range of
alternative solutions based on need and a method of evaluating the chosen solution.

One important aspect of the systems approach is the use of the visual representation of the decision-making process in a flowchart. Figure 1 shows Popham and Baker's goal-referenced instructional model. Illustrating the systems approach in four steps, the model is simple yet functional in showing the progression from specification of objectives, pre-assessment, and instruction, to evaluation and revision or augmentation. More complex models will be presented and explained later in this chapter.

Pfeiffer (1968) saw the application of the systems approach at three different levels in education. First, it can be used by whole school systems of cities, states, or
even an entire nation. Second, it can be used to make decisions at individual institutions. Third, it can be used in developing individual courses and teaching methods. It is the third level that will be emphasized in the rest of this paper, since it was at this level that instructional materials were developed for teaching metric temperature. The systems approach to developing educational materials will be presented in two main steps: identification of the problem and resolution of the problem.

Identification of the Problem

The first step in solving a problem, educational or otherwise, is to identify how things are and how they should be. Kaufman (1972, p. 5) referred to this as "the measurable discrepancy (or gap) between current outcomes and desired or required outcomes." The discrepancy between "what is" and "what should be" may be referred to as an educational need.

Once needs are established, the systems analyst is in a position to write behavioral objectives to meet these needs. Much has been written about writing good behavioral objectives. Banathy (Resnick, 1972, p. 157) recommended that behavioral objectives include

1. **What** the learner is expected to be able to do, by
   a. Using verbs that denote observable action.
   b. Indicating the stimulus that is to evoke the behavior of the learner.
c. Specifying resources (objects) to be used by the learner and persons with whom the learner should interact.

2. How well the behavior is expected to be performed by identifying
   a. Accuracy or correctness of response.
   b. Response length, speed, rate, and so forth.

3. Under what circumstances the learner is expected to perform by specifying
   a. Physical or situational circumstances.
   b. Psychological conditions.

Similarly, Tuckman and Edwards (1971) referred to Mager's definition of behavioral objectives as containing statements of performance, criteria, and conditions.

It has become the "in thing" in education to write behavioral objectives, if for no other reason than to be modern. With many unknowledgeable people writing objectives, "goal distortion" often results. Hartley (1969) described goal distortion as emphasizing the goals most easily measured and neglecting the goals that cannot be quantified and measured, often more important goals. Wong and Wong (1972, p. 57) were also cautious about the improper use of behavioral objectives:

Lately there has been a great ballyhoo about the setting of behavioral objectives. Often it appears that the idea of setting objectives is furthered as an end in itself. To the systems-oriented teacher objectives are only valuable when they are based on data he has gathered about his students and when they are used as precisely stated purposes to guide the selection of the most effective learning processes and content.

They seemed to feel that behavioral objectives should be
individualized to the people for whom they are being written.

Many model flowcharts are available on the systems approach to developing instructional materials. They, too, must be individualized to the situation in which they are used to be of value. One fairly adaptable flowchart developed by Banathy (Resnick, 1972, p. 160) is shown in Figure 2. The boxes contain the steps of the procedure,

--- feedback line

Figure 2
An Over-All Structure of the Design of an Instructional System
the solid arrows showing their sequencing. The dotted line shows the feedback line, indicating that there is always opportunity for revision and improvement. It can be seen by the flowchart that evaluation devices, as shown in Box II, are developed even before the learning task is analyzed and teaching materials developed. At no point on a flowchart should there be a completion box: the feedback line is fundamental to the flowchart in using the systems approach.

Figure 3, developed by Tuckman and Edwards (1971, p. 21), illustrates another model for instructional management. The activities they have included under the area labeled "Analysis" are comparable to the activities labeled "Identification of the Problem" in this chapter.

Figure 3
A Systems Model for Instructional Management
The third step, "Specifying a Sequence for Behavioral Objectives (Structural Analysis)" would include the development of the flowchart. The areas labeled "Synthesis" and "Operation" are analogous to "Resolution of the Problem" as presented in this paper. Again, the feedback line allows for revision.

Figure 4, page 17, shows a more complex model developed by Penta (1973, p. 13). The arrows on this particular flowchart move from top to bottom. Parallel arrows indicate that activities may occur simultaneously. An example can be found at the top where parallel arrows point to "Identify Need and Purpose" and to "Complete Pre-Planning Package." There is no step on this model that cannot be reached by the feedback line for the purpose of rethinking or revision.

Resolution of the Problem

The first aspect of this part of the problem-solving process is to seek as many solution alternatives as possible. This involves actively searching for new ideas rather than only those that are readily available. A great many resources need to be considered before any are singled out for use. At this point in the systems approach, many novice systems analysts accept the use of self-instructional programming and/or computed-assisted instruction without considering other alternatives. While it is true that individualized instruction is often used in the systems
Figure 4
Development of Instructional Materials—Systems Model
approach, a number of alternative solutions must be con-
sidered before a selection of an instructional method or combination of methods is made. From among all the pos-
sible solutions offered, one or more must be selected, implemented, and evaluated.

Tuckman and Edwards (1971) differentiated between three types of evaluation that are used in the systems approach. The first type is individual evaluation that tells how the student is doing. The second type is forma-
tive evaluation, which occurs concurrently with instruction, evaluating behavioral objectives and their sequencing to see how instruction is going. Summative evaluation is the overall evaluation of the final instructional package.

Eisele (1973) felt that if a student does not meet the objectives, it is not the student that failed, but rather the system that failed. Unlike traditional evalua-
tion, which is concerned with categorizing people as fail-
ing, average, and above average, the systems approach is humanistic. It assumes instructional success for all. Until this goal is met, the feedback line on the flowchart facilitates unlimited revision opportunities. Baker (Travers, 1973) cited two sources of data which may lead to revision: student responses during instruction and post-
test responses. Only when the instructional materials meet their objectives for most of the students who use them are the materials considered ready for use.
POTENTIAL OF THE SYSTEMS APPROACH FOR DEVELOPING INSTRUCTIONAL MATERIALS

Flanagan (1970, p. 65) stated, "It is very difficult to argue against the systems approach. It does not require that one accept any specific set of values or purposes for education". The approach does involve some strong commitments, however. Kaufman (1972) listed these as commitment to planning; commitment to tools of planning, including needs assessment and system analysis; and commitment to use the information that results.

Monetary considerations are one of the biggest drawbacks to the use of the systems approach. Since most teachers and administrators have not been trained to implement the systems approach, it has often been assigned to a few professionals in systems analysis. Its use in the classroom, therefore, is not widespread. Beilby (1974) was convinced that teachers must get involved in instructional development as there is not enough money and time available to have only professionals involved. This includes much more than just the teacher's time. Root (1973) recognized many factors involved including the teacher's interest in instructional development, commitment, training, and administrative support.

Locatis (1973) predicted a drawback to the systems approach in the fact that once an instructional package has undergone the expense of preparation and validation, a
school is unlikely to change and update it because of further expense. He offered suggestions to counterbalance some of the problems of instructional development by becoming more concerned with the ends of education, being more accepting of nonbehavioral (perhaps affective) objectives, developing better information retrieval and exchange, and clarifying technical language.

The real potential of the systems approach in preparing instructional materials is evident. Penta (1973) listed three main advantages: 1. resources are better utilized, 2. the systems model helps to clarify the planning and production process, and 3. elements of the system are clearly delineated and can be readily analyzed for improvements. The time has come that education have the same resources for decision-making that have facilitated business and government for years. The systems approach is that facilitator, and its potential in the field of education is just beginning to be tapped.
Chapter 3

DEVELOPING THE SELF-INSTRUCTIONAL SYSTEM

PURPOSE OF THE STUDY

The purpose of this study was to empirically develop a self-instructional system to teach the everyday, non-industrial, use of metric temperature. The teaching system was to be flexible enough to be suitable for either adults or students in at least tenth grade, regardless of age or sex, and was to be appropriate for use either in the classroom or in the home. Empirical development of the system involved initial writing of the teaching materials and evaluation devices in preliminary form, trying them out, revising them several times, and field testing the system to evaluate how well its objectives had been met.

ORIENTATION TO METRIC TEMPERATURE

When this project was first conceived, the researcher had limited knowledge of both the metric system and, more specifically, Celsius temperature measurement. In the spring of 1974, the writer visited the campus of Northern State College at Aberdeen, South Dakota, along with her adviser and two other graduate students to gain a general orientation to metric measurements as they were
being used in industrial arts to prepare students for industrial uses.

Available teaching materials were reviewed, largely bulletins, mimeographed materials, and transparencies for use with an overhead projector. It became apparent that, in general, the standard conversion formula from Fahrenheit to Celsius¹ was used with little further information other than freezing and boiling points, room temperature, and body temperature. Conversion slides and charts that were reviewed were generally of limited use; those that measured freezer and cold weather conditions seldom had a range high enough to use the same slide to determine conversions of cooking temperatures.

The researcher responded very favorably to the idea of approximating Celsius temperatures suggested by Gilbert and Gilbert (1973) and saw real potential in combining the estimation procedure with conversion slide usage when great accuracy was necessary.

USE OF THE SYSTEMS APPROACH

Because of its potential in the development of truly useful and effective teaching materials, the systems approach was chosen as an organized method of developing materials to teach Celsius measurement. The researcher

\[ 1 \, ^{\circ}C = \frac{5}{9}(^{\circ}F - 32) \]
reviewed the literature on the systems approach, applying the procedure specifically to the development of Celsius instructional materials.

Figure 5 shows the procedure followed in developing the teaching materials. The procedure followed is based on Johnson and Johnson (1970). The five steps illustrated

![Diagram of the procedure](image)

**Figure 5**

Procedure Used in Developing the Celsius Instructional Materials
in the flowchart have been used to organize the following five sections of this chapter.

Specifying and Analyzing Objectives

The first step in developing the teaching materials was to analyze the area of metric temperature and decide what things a person ought to be able to do to show proficiency in Celsius measurement. These behaviors were to be the objectives of the instructional system. As learner behaviors were written down, some of them, such as reading thermometers accurately and using Fahrenheit measurement, were set apart as prerequisite skills, to be assumed and not taught.

The researcher felt that it was important to include some higher-level objectives that measured beyond memorization of specific temperatures and conversion formulas. It was believed that if the learner could understand the ratio of Fahrenheit to Celsius temperatures, he could also estimate Celsius temperatures that did not require great accuracy. This process is based on concept formation and the ability to apply principles, processes which are higher in the Taxonomy of Educational Objectives (Bloom, 1956) than recall of information memorized.

These objectives were referred to as criterion objectives or observable performance tasks. Mastery of the use of Celsius measurement could be ascertained if a person
was able to perform the following five criterion objectives:

The student... 

1. approximates the conversion of Fahrenheit to Celsius temperatures using the formula \( C = \frac{F}{2} \) for temperatures over boiling and the formula \( C = \frac{F}{2} - 15 \) for temperatures under boiling.

2. approximates without the use of conversion instruments common Celsius temperatures such as room temperature, outdoor temperatures, body temperature, and the freezing and boiling temperatures of water.

3. explains that the range between two adjacent Celsius integers is larger than between two adjacent Fahrenheit degrees at the ratio of \( 5\degree C = 9\degree F \).

4. chooses among various thermometer ranges the appropriate one for a specific use.

5. converts Fahrenheit temperatures to Celsius measurements and vice versa using a conversion slide.

The researcher believed that being able to perform these five tasks, or achieve these criterion objectives, would adequately demonstrate the learner's mastery of the use of the metric temperature.

Developing Evaluation Instruments

System effectiveness required a measurement procedure to observe and record degree of attainment of the educational objectives. This measurement or evaluation procedure could then be used to secure feedback for use in up-grading the quality of the teaching system.
Since all learners could not be expected to achieve the same degree of mastery, a minimum performance standard for assessing system success was arbitrarily set at 80 percent of the learners achieving 80 percent or better on a post-test following instruction.

Both a pre- and post-test were written. To assure parallel tests, the items were written all at once and then divided into two tests of equal difficulty and weight. One half became the pre-test and the other became the post-test. The tests were limited to 32 questions to avoid disinterest and fatigue. Both tests were weighted the same with each objective\(^2\) being stressed as follows: Objective 1, 30 percent; Objective 2, 30 percent; Objective 3, 9 percent; Objective 4, 16 percent; Objective 5, 15 percent. While Objective 2 called for mere memorization, the other objectives called for application of procedures and principles to actual temperatures or thermometers.

**Arranging Instructional Activities**

Before the writing of instructional materials began, an outline was necessary to organize what steps were necessary to reach each objective and what sequence of steps would be most effective in getting to the mastery level.\(^3\)

---

\(^2\)See p. 25.

\(^3\)80 percent accuracy on the post-test
At this point it was decided to move from the simple to the complex by having the students first learn specific reference points; then move on to approximations; and finally, identify what type of thermometer would be used to measure within a given Celsius temperature range. One section would also be developed to teach the use of a conversion slide.

Because Celsius measurements would require a good deal of memory and manipulation, it was decided to include many relevant examples for drill and some spaced review. Maintaining student interest during drill of basic knowledge was recognized as a potential problem.

Selecting and Designing Methods and Materials

Designing self-instructional materials that could be used in the home as well as the classroom limited the researcher to the use of methods and materials that required no teacher present and no expensive equipment. Presentation through lecture was ruled out, as were video tape and films, due to their impracticality and distribution problems for home use. A cassette tape with supplementary visuals was considered, but the idea was abandoned due to the expense of the required equipment.

The researcher had assisted in the revision of a self-instructional sewing system utilizing programmed booklets and separate visuals. This approach seemed appropriate
for teaching Celsius measurement, provided programmed booklets could be printed inexpensively and supplementary materials could be produced in adequate numbers for home use.

At this point the decision was made not to include actual thermometers as part of the learning system. If actual thermometers were provided, temperature conditions would have to be manipulated to provide the subjects opportunities to measure a variety of temperatures in Celsius measurement. Learning by using thermometers would have required cooking facilities; water; refrigeration; and, perhaps, sick bodies. It would also have required a large investment in thermometers to go with each programmed booklet. Since being able to read a Fahrenheit thermometer had already been stated as a prerequisite to the program, it was decided to teach metric temperature using printed pictures of thermometers.

Writing a programmed instruction booklet required a study of programs and of instructions in how to program effectively. The first rough draft was written on small sheets of paper with the answers folded to the back of the page, as seen on similar programs being written by other graduate students. Illustrations were included as needed. Early revision of frames, applying principles presented by Markle (1964), attempted to insure that all important information be included in student responses and that all
information not related to the specific five objectives be eliminated. The researcher attempted to get the students to think in metric measurement by the end of the booklet by phasing out references to Fahrenheit and completely eliminating its mention on the final review.

Recognizing a real potential for boredom on the part of the learner in drilling and reviewing specific reference points to be learned, the researcher developed three sets of playing cards. The first set taught weather and water temperatures; the second set taught body temperatures, both normal and abnormal; and the final set was a review of the first two sets, to be used at the very end of the program.

Originally, all three card games were planned to be on self-adhesive vinyl-covered playing cards. The amount of time required to prepare the cards and the necessity to have sets of at least Card Sets A and B with each program booklet made it impractical to produce. Since they would be used only two times each for testing purposes, paper rather than vinyl-covered cards was a sufficiently durable material. Fifty copies of Sets A and B were duplicated by a mimeograph machine. They were printed on colored paper and marked "A" or "B" in the upper lefthand corner to distinguish them.

The games involved matching card pairs or trios: descriptions of temperatures, Celsius temperatures, and
Fahrenheit temperatures. An example of a set to be matched from Card Set B is

"Normal Body Temperature"
(on yellow paper)

"37°C"
(on pink paper)

"98.6°F"
(on blue paper)

The B deck contained four other similar sets to be matched while playing the game. Card Set A contained eight pairs of cards and Card Set C contained 26 pairs and one "Metric Match -40" card to be used as an "Old Maid."

Card Set C was intended for either group or solitary review, so not as many sets were needed. Because they would be used more often, the cards had to be more durable than those in Card Sets A and B. Card Set C was produced on regular playing cards covered with self-adhesive vinyl on the number side. To simplify matching pairs, red ink was used for writing Celsius temperatures and either blue or black ink was used for writing descriptions of weather and body conditions. No Fahrenheit temperatures were included on the final card set to encourage the learner to "think metric" rather than to merely think in Fahrenheit and then convert to Celsius. Ten sets of these cards were produced. Sample cards from Card Set C have been included in Appendix A, p. 60.

Conversion slides or charts of suitable quality had
to be provided with each set of self-instructional materials. Mimeographing a conversion chart or slide was contemplated, but lack of accuracy was limiting. Slides that could be purchased locally or by mail generally had temperature ranges too low for oven measurements and involved prohibitive expense. About 150 conversion slides distributed by the Army National Guard were made available at no cost and were used in the project. The temperature range of the slides extended from cold weather conditions to cooking temperatures, as wide a range as would be encountered in the home. The slides, normally marketed at more than a dollar apiece, were now available in sufficient quantity to be given to subjects following the completion of the program in appreciation for their cooperation. Fifty conversion slides would be retained as part of the original fifty sets of self-instructional Celsius materials.

The potential for teaching the program on computer terminals was considered but ruled out for lack of terminals available to test subjects. At the same time, however, the researcher decided to utilize a computer keyboard terminal for writing the program and then have the programmed booklets reproduced as a long computer printout. This accordion-pleated printout could be refolded and bound with much less time and effort than would have been necessary to produce the originally contemplated mimeographed
booklet. Additional expense encountered by involving the computer was to be minimal.

The decision to duplicate the booklet by computer involved two major problems: the researcher was unfamiliar with computer programming, and the printouts could include none of the following symbols, not found on the printer: ? " : _ O. The supervisor of computer-assisted instruction on campus familiarized the researcher with the use of the terminal for programming and making program corrections.

The absence of certain computer characters required changes. The question mark was replaced by a series of five hyphens (-----) whenever a response was sought, as follows:

IN YOUR OWN WORDS, WHAT ARE THREE DIFFERENT APPROACHES USED TO COMPARE FAHRENHEIT TEMPERATURES TO CELSIUS TEMPERATURES.-----

Quotation marks were replaced by apostrophes, and colons were either eliminated or else commas were substituted. When underlining was unavoidable, as in the pronunciation of the word "Celsius," hyphens were used on the line below the word to be underlined:

CELSIUS IS PRONOUNCED 'SELL SEE US' AND IS ----

SPELLED WITH ONLY ONE C.

Finally, the word "degrees" was written out rather than abbreviated; for example, 7 DEGREES C rather than 7°C. The word was abbreviated, however, on the playing cards. All
writing in the programmed booklet was printed as capital letters by the computer. Sample frames can be found in Appendix A, p. 62.

**Refining the Instructional System**

In addition to the pre- and post-tests, an attitude sheet was developed to be filled out by each subject following his going through the program. This "Sound Off" sheet may be found in Appendix B, p. 66. This questionnaire was designed to record the subject's attitudes toward three things: the Celsius program, the use of metric temperature, and self-instructional programs in general. Questions were also provided to record the subject's sex; age; educational background; and, in the case of those who had attended high school, high school class rank. An open-ended sentence was included to encourage further comments or suggestions about the system. The data to be collected from the "Sound Off" sheet were intended for evaluating attitude toward the system and for testing hypotheses following field testing. The amount of time spent on the program was included with the subject's name and the date of the post-test.

After all the materials used in the system were developed, preliminary test subjects were sought. Ninth and tenth grade subjects representing the average ability of homemakers for whom the system was designed were chosen
for preliminary testing. The researcher observed and recorded problems encountered as each of the five subjects went through the instructional materials and evaluations. Revision followed each of the five trials. Except for the third and fourth subjects, who participated simultaneously, all subjects worked one at a time.

Changes were made in the system where preliminary subjects expressed confusion or hesitation; where answers were missed in the programmed booklets, particularly on criterion-referenced pages; and where questions were missed on the post-test. For any changes that were made on the post-test, parallel changes were made on the pre-test to keep them of equal difficulty. The preliminary subjects also offered assistance in wording the instructions for Card Set C for greatest clarity.

The resulting refinements of the instructional system included clarifying the directions and some items on the pre- and post-tests, adding several pages in the programmed booklet, clarifying statements on the answer pages of the programmed booklet, rewriting one of the visuals, and rewording the "Sound Off" sheet.

The completed, revised instructional system consisted of the following nine parts:

1. A two-part pre-test requiring the use of a conversion slide on the second part
2. A metric conversion slide
3. A bound computer-printed programmed booklet with 108 pages

4. Card Set A consisting of 16 cards to learn Celsius weather and water temperatures

5. Card Set B consisting of 15 cards to learn Celsius body temperatures for different degrees of fever

6. A visuals booklet containing five pages of illustrations for reference and review

7. Card Set C consisting of 53 cards to review Celsius weather, water, and body temperatures and conversion formulas for estimating Celsius temperatures from Fahrenheit temperatures

8. A two-part post-test requiring the use of a conversion slide on the second part

9. A "Sound Off" sheet to record personal data and attitude toward the program as well as attitude toward Celsius temperature measurement

Once all changes had been made, all materials were duplicated in the following quantities: 50 programmed booklets, Card Sets A and B, and the visuals booklets; ten copies of Card Set C; 150 conversion slides; 160 copies of the pre-test; and 120 copies of the post-test and "Sound Off" sheet. A cartoon cover sheet was added to the post-test for interest.
Chapter 4

FIELD TESTING THE SELF-INSTRUCTIONAL PROGRAM

After the instructional system had been revised and printed in its nine parts, it was ready for field testing. It was the goal of field testing to have a wide variety of subjects achieve mastery-level performance on a post-test following completion of the self-instructional materials. Success would be marked by 80 percent of the subjects achieving at least 80 percent accuracy on the post-test.

SOURCE OF SUBJECTS

All subjects were either adults or students in at least the ninth grade. Adults were chosen who had not attended or graduated from high school as well as some who were attending or had graduated from post-secondary educational institutions. Students from both public and private high schools participated.

More than 150 subjects took the pre-test and checked out teaching materials, but only 106 completed the learning system, including the post-test. About ten subjects, all males, disqualified themselves from the research data by scoring 80 percent or better on the pre-test. Approximately 35 other subjects were eliminated from the data analysis because they did not complete the system.
The 106 subjects who completed the system are described in Table 1. Student subjects were primarily from Bethel, Maine, while the largest number of adults came from Brookings, South Dakota, and Bemidji, Minnesota. A total of 58 females and 48 males participated. High school students accounted for 61 of the subjects, and adults accounted for the other 45 subjects. The subjects fell into the following age categories:

Table 1
Description of Subjects

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telstar Regional High School</td>
<td>Bethel, ME</td>
<td>Students</td>
<td>44</td>
</tr>
<tr>
<td>SDSU School Lunch Workshop</td>
<td>Brookings, SD</td>
<td>Adults</td>
<td>19</td>
</tr>
<tr>
<td>Gould Academy</td>
<td>Bethel, ME</td>
<td>Students</td>
<td>17</td>
</tr>
<tr>
<td>Camping Staff Oak Hills Fellowship</td>
<td>Bemidji, MN</td>
<td>Adults</td>
<td>15</td>
</tr>
<tr>
<td>Evans Notch Forest Rangers</td>
<td>Bethel, ME</td>
<td>Adults</td>
<td>6</td>
</tr>
<tr>
<td>Masonic Lodge Members</td>
<td>Bethel, ME</td>
<td>Adults</td>
<td>3</td>
</tr>
<tr>
<td>Farmers</td>
<td>Bethel, ME</td>
<td>Adults</td>
<td>2</td>
</tr>
</tbody>
</table>

106
<table>
<thead>
<tr>
<th>Age</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 19</td>
<td>61</td>
</tr>
<tr>
<td>19-35</td>
<td>17</td>
</tr>
<tr>
<td>36-55</td>
<td>22</td>
</tr>
<tr>
<td>over 55</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
</tr>
</tbody>
</table>

INSTRUCTIONAL CONDITIONS

Most of the student subjects completed the pre-test in the presence of the researcher before being given the instructional materials. Adults were generally given a copy of the pre-test to take at home before going through the instructional materials. Once the instructional materials had been given to a subject, no attempt was made to control outside influences. Participants were told to complete the program by following the instructions in the programmed booklet and referring to the supplementary materials as instructed by the booklet. When they had finished the program, they returned all materials and took a post-test.

Most of the adult subjects studied the materials in their homes, places of business, dormitory rooms, or camp cabins. Student subjects from the public school used the materials strictly in their science classrooms, but student subjects from the private school were expected to spend one evening working on the program in their dormitory
rooms as well as one science class and one science lab period.

Each subject estimated the amount of time he spent on the program. The range extended from one half to six hours, the average being three hours. Subjects were encouraged to play the final card game with others if they so wanted. Several subjects indicated that they enjoyed the game to the extent that they continued playing with Card Set C beyond the time that it took them to learn the temperatures; this may explain some of the longer times. None of the five preliminary subjects who were actually observed by the researcher needed more than three hours to complete the program.

The first group presentation of the teaching system included the J. C. Penney "Metric Song" cassette recording following the pre-test to create interest in all areas of metric measurements. It was decided to eliminate the audio-visual aids in subsequent presentations to save presentation time and the effort of securing the AV equipment required. It also simplified the presentation to individuals not contacted in a group.

All post-tests were administered with the researcher, the thesis adviser, or the classroom teacher present. Typing corrections were pointed out, and directions were clarified for the subjects. Conversion slides were permitted only on the second part, which required
their use. The "Sound Off" attitude sheet, which may be found in Appendix B, p. 66, was filled out by subjects following completion of the entire Celsius teaching system. After the post-tests and attitude sheets were turned in, students were told their pre-test, post-test, and gain scores.
Chapter 5

ANALYSIS OF DATA

The goal of the system was to have at least 80 percent of the subjects achieve mastery-level (80 percent or better) performance on the post-test following instruction. It was also of interest to the researcher to discover what factors played a part in the performance of the subjects. This chapter explains how the research data were collected, analyzed, and interpreted.

COLLECTION OF DATA

Research data consisted of two types: scores on the evaluation instruments and responses on a "Sound Off" sheet filled out after the post-test was completed.

Data from Evaluation Instruments

The pre- and post-tests were developed to attempt to determine the amount of knowledge gained by a student going through the programmed teaching materials on metric temperature. The tests were developed in parallel forms with 32 items in the pre-test paired with an equal number of items in the post-test. The pairs contained items of presumed equal difficulty that tested the same concepts. An attempt was made to use the same instructions, similar
question wording, and questions involving the same difficulty of mathematical computations on each of the 32-question tests. A copy of the post-test may be found in Appendix B, p. 68.

Most of the subjects were able to complete the post-test in about 20 minutes. The pre-test took anywhere from a few minutes, for those who knew nothing about metric temperature and quickly guessed, to several hours, for those who had some idea of a conversion formula and proceeded to work out each question mathematically. The evaluation instruments were kept short to retain student interest and to prevent time pressure during a class period when used in schools.

Two typing errors were changed in ink on the post-test. No attempt was made to determine whether drawing special attention to the items improved the subjects' performance on these items. There were no ink corrections on the pre-test.

Data from the "Sound Off" Sheet

After post-testing was completed, the subjects were each asked to complete, as honestly as possible, a questionnaire titled "Sound Off." A copy of this questionnaire may be found in Appendix B, p. 66. The first item asked the subject to describe his feeling(s) about the program by checking as many adjectives as might apply. The list of 12
adjectives contained five positive and seven negative descriptions of attitude. Counting each positive modifier checked +1 and each negative modifier checked -1 would result in a neutral score of zero and a scale from -7 to +5. It was desirable to work with positive numbers, so the scale was transcribed to a scale from 1 to 13 with a neutral score of 8.

The second item attempted to rate a person's feeling of the relevance of the knowledge of metric temperature to his daily life by checking one of four choices: not at all, a little, quite a bit, a lot. These were considered a four-point scale.

The third item intended to rate self-instructional programming with other methods of learning by asking the subject to check his favorite three of the seven methods listed for learning the metric system.

Other items asked the subject to indicate sex, education and graduation levels, age range, and approximate high school class rank by quartiles. Each required only a check mark or a circle. The amount of time spent on the program was requested at the beginning of the post-test, rather than on the "Sound Off" sheet.

Students were also given a chance to express their feelings through the open-ended statement, "Looking back on this course I feel. . . ." Most subjects filled in from one word to several sentences, often repeating what they
might have indicated on the attitude or relevance items earlier.

PROCEDURE FOR DATA ANALYSIS

Data were analyzed using the Statistical Package for the Social Sciences on the South Dakota State University computer. Histograms were constructed to determine the graphic curves of pre- and post-test scores.

Scattergrams showing the relationships of all other factors with both pre- and post-test scores were generated to indicate further correlation studies of value. Finally, multiple regressions were computed to link independent variables to post-test scores, pre-test scores, and attitude ratings.

FINDINGS

Figure 6 shows the distribution of 106 pre-test scores. As mentioned earlier, subjects with pre-test scores of 80 percent or more were not included; thus, no scores exceed 80. Scores extended from 6 to 79 with a range of 73. The pre-test mean was 38.3, the median 36.5, and the mode 21. It may be observed that there was considerable variability among subjects in their previous knowledge of metric temperature. Although this histogram does not approximate a normal curve, it is relatively symmetrical.
Figure 6

Histogram of the Pre-test
Frequency Distribution

Figure 7

Histogram of the Post-test
Frequency Distribution
Of most concern was a distribution of post-test scores to see if the mastery level had been reached by 80 percent of the subjects. Figure 7 shows the histogram of the post-test frequency distribution. Scores extended from 58 to 100 with a range of 42. The distribution was definitely skewed to the left rather than a normal curve. The histogram pictures what would be considered ideal for a criterion-referenced evaluation device. It illustrates the large percentage of subjects who attained the mastery level following completion of the learning system.

The same distribution of post-test scores is shown in table form in Table 2. It can be noted that only 17 percent or 18 subjects had post-test scores below the system goal of 80 percent. Therefore, 83 percent or 88 subjects achieved mastery-level performance on the post-test. Three percent more people achieved mastery-level performance than needed to indicate system success. The mean score on the 100-point test was 89.6, the median 93.8, the mode 100, and the standard deviation 11.1. The gains from pre-test to post-test scores ranged from 18 to 82 percentage points, with an average of 51.3 points gained.

The multiple regression tests showed that two factors were significant in forecasting performance on the post-test. Generally, the better a person did on the pre-test and the more relevant a person felt Celsius temperature measurement to be, the higher his post-test score.
The pre-test performance accounted for 11.07 percent of the variance, and the relevance rating accounted for another 4.78 percent of the variance. The prediction equation is Formula A in Appendix C, p. 71.

Table 2
Frequency Distribution of Post-test Scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>23</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>97</td>
<td>19</td>
<td>18</td>
<td>78</td>
</tr>
<tr>
<td>94</td>
<td>15</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>91</td>
<td>12</td>
<td>11</td>
<td>46</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>89</td>
<td>1</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>88</td>
<td>4</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>86</td>
<td>1</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>85</td>
<td>4</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>83</td>
<td>3</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>82</td>
<td>3</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>80</td>
<td>2</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>79</td>
<td>1</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>77</td>
<td>1</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>76</td>
<td>3</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>74</td>
<td>1</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>73</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>71</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>70</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>67</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>66</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>65</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>64</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>62</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>58</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Pre-test scores were affected by two main independent variables. First, there were generally higher pre-test scores for those subjects who had completed higher levels of education, as indicated by the subjects circling the level of educational institutions from which they had graduated. Second, males generally scored higher on the pre-test than females. It was mentioned earlier that no females scored over 79 percent on the pre-test, compared to about ten males who tested out of the program. It should be noted, however, that females averaged higher gain scores to the point that there was no significant difference in the performance of males and females on the post-test. Statistically, graduation level accounted for 9.1 percent of the pre-test score variance and sex accounted for 6.3 percent. The prediction equation is Formula B in Appendix C, p. 74.

Another multiple regression test was run to determine what factors influenced the subjects' attitudes toward the program. A strong statistical correlation was found between how much a subject felt he would use his knowledge of metric temperature (relevance) and his attitude toward the program. Because relevance and attitude appeared to be so inter-related, the correlation was deemed not significant from a practical standpoint, even though it was statistically significant.
There was evidence that females generally had a more favorable attitude toward the program than males. Sex accounted for 6.3 percent of the variance in attitude. No other factors were significant in predicting attitude toward the program.

The class rank ratings that the subjects gave themselves were questioned for their validity. Out of 106 subjects, only two classified themselves as having been in the bottom fourth of their high school class. Three fourths of the subjects ranked themselves in the top half. Of 18 subjects taking low-level chemistry, half ranked themselves as being in the top half of their entire junior class. Because it appeared to lack validity, high school class rank was not used in any of the correlation studies.

Three other areas of responses could be noted. First, on a scale of attitude toward the program from 1 to 13 with 1 being extremely negative, 8 neutral, and 13 extremely positive, subjects scored as follows:

<table>
<thead>
<tr>
<th>Attitude Score</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>neutral</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
</tr>
</tbody>
</table>

No scores were below six. Over 95 percent of the subjects
indicated favorable attitudes toward the system with over half of them receiving highly positive scores of 12 or 13. This indicated strongly positive attitudes toward this program. Only about 5 percent of the subjects checked more negative than positive adjectives describing their feelings about the program.

Second, when asked how much they wanted to use their new knowledge of metric temperature, subjects responded on the following four-point relevance scale:

<table>
<thead>
<tr>
<th>Relevance</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>not at all</td>
<td>5</td>
</tr>
<tr>
<td>a little</td>
<td>52</td>
</tr>
<tr>
<td>quite a bit</td>
<td>29</td>
</tr>
<tr>
<td>a lot</td>
<td>17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>103</strong></td>
</tr>
</tbody>
</table>

Generally, the people who went through the Celsius program did not see a lot of use for it at this time. Less than 5 percent saw their new knowledge as something that they did not want to use at all, though.

Third, when asked to check the three methods by which they most preferred to learn the metric system, nearly half of the subjects did not follow the directions and checked only one method. Of the 47 who checked only one method, 40 checked "self-instructional program (like this)." It is possible that they liked this program so much that they did not want to also check an alternative
method. About 90 percent of the subjects checked "self-instructional program (like this)" as one of their choices, clearly the preferred method. It is clearly evident that, in general, the subjects had a very positive attitude toward self-instructional programming, perhaps toward this program especially.

Item difficulty was determined on the post-test. The only two questions missed by over 20 percent of the subjects both involved division and subtraction of negative numbers. Neither was missed by more than 23 percent of the subjects, however. Difficulty was also shown in stating the ratio between the Celsius and Fahrenheit scales and in comparing ranges on the two scales. The only item with no errors asked subjects the Celsius boiling temperature of water. Generally, students performed better on questions involving rote memory than on those involving mathematical conversions or understanding of relationships between the two measurement systems.
Chapter 6

SUMMARY AND RECOMMENDATIONS
FOR FURTHER STUDY

SUMMARY

The objective of this study was to develop a self-instructional system for teaching metric temperature which met the following criteria: individualized, enjoyable, inexpensive, suitable for home use as well as classroom use, and appropriate for use by homemakers and consumers rather than industry. Mastery-level learning was arbitrarily set at students achieving 80 percent or better on the post-test. The system goal was for 80 percent of the subjects to learn Celsius to the mastery level.

The system was designed for students in at least the tenth grade and for adults. Any participants scoring at least 80 percent on the pre-test were given the option of completing the system, but their results were not included in the research data. The research data of all persons with scores of less than 80 percent on the pre-test who indicated they finished the book were used in correlation studies, whether or not they had completed the third card game.

The entire system consisted of a pre-test, a self-instructional programmed booklet, a visuals booklet, a
conversion slide, three card games, a post-test, and a device to evaluate attitude toward this metric teaching system. When the teaching system had been developed, five high school students worked through the materials independently for the purpose of revision.

Participating subjects included South Dakota school food service employees; Minnesota Bible camp counselors; and Maine students in public and private high schools, forest rangers, Masonic Lodge members, and farmers. Sets of materials were given to over 150 people, but only 106 completed the program.

Field testing established system success when 83 percent of the subjects scored 80 percent or better on the post-test, 3 percent above the researcher's goal. Almost one fourth, 22 percent, of the subjects scored 100 percent on the post-test. Scores increased an average of 51 percentage points between pre- and post-tests. There were positive correlations between pre-test scores and post-test scores and between a feeling of relevance in using Celsius measurement and post-test scores. Generally, subjects saw a low degree of relevance in learning Celsius temperature measurement but indicated overwhelmingly that they preferred to learn to use it with a self-instructional program rather than with other teaching techniques.
RECOMMENDATIONS FOR FURTHER STUDY

Revising the Self-instructional System

The following suggestions or revisions are recommended for improvement of the self-instructional system to teach metric temperature:

1. Simplify instructions on the pre- and post-tests to minimize the need for teacher explanation.

2. Test the evaluation instruments for reliability.

3. Expand the parts of the program that teach negative temperature conversion.

4. Encourage mathematical and conversion slide accuracy even more than the system presently does.

5. Revise Visual 3 for easier distinction of cold-weather temperatures.

6. Put a hard cover on the programmed booklet.

7. Adapt the system for use with computer-assisted instruction.

8. Suggest home or classroom follow-up activities for better retention of learnings.
Recommendations for Further Research

The following areas of research are recommended for further study:

1. Develop similar self-instructional systems to teach other areas of metric measurements, such as length, volume, weight, and area.

2. Repeat this study after Congress has acted decisively about setting recommendations and dates for conversion to metric measurement to determine if increased relevance changes performance results.

3. Perform a follow-up study to determine how much metric knowledge is retained after a lapse of one month, six months, and one year, correlating the results with the number of opportunities for use of metric temperature by the subjects.

4. Prepare and evaluate a system for teaching metric measurements to upper-elementary and junior high students.
REFERENCES CITED


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APPENDIX A

INSTRUCTIONAL MATERIALS
SAMPLE PAIRS FROM CARD SET C

Thirsty Summer Day

30°C

Boiling Water

100°C
Flu

39°C

Low-grade fever

38°C
212 DEGREES FAHRENHEIT = 100 DEGREES CELSIUS

WATER BOILS AT ---- DEGREES CELSIUS.

(100)

BECAUSE THE UNITS ON THE TWO SCALES ARE DIFFERENT, AN OUTDOOR TEMPERATURE RISE FROM 80 DEGREES FAHRENHEIT TO 85 DEGREES FAHRENHEIT WOULD BE MUCH LESS APPARENT TO THE HUMAN BODY THAN A FIVE-DEGREE RISE FROM 25 DEGREES CELSIUS TO 30 DEGREES CELSIUS.

WHICH WOULD BE MORE CRITICAL, A BODY TEMPERATURE RISE OF FOUR DEGREES CELSIUS OR A RISE OF FOUR DEGREES FAHRENHEIT ----.

(FOUR DEGREES CELSIUS)

THE OPERATING TEMPERATURE OF AN AUTOMOBILE ENGINE IS 180 DEGREES F. THIS IS ROUGHLY THE SAME AS ---- DEGREES C.

(75)
YOU LEARNED EARLIER THAT -40 DEGREES F. IS EXACTLY
--- DEGREES C.

USING THE APPROXIMATION CONVERSION, -40 DEGREES F.
IS ABOUT --- DEGREES C.

(-40, -35)

[IF YOU HESITATED ON THE SECOND ANSWER, GO BACK AND REVIEW
PAGES 50, 58, AND 60 BEFORE GOING ON. ALSO, REMEMBER TO
WATCH YOUR SIGNS WHEN SUBTRACTING NEGATIVE NUMBERS.]

BOTH NEGATIVE AND POSITIVE NUMBERS GET BIGGER AS
YOU MOVE (AWAY FROM/TOWARD) --- ZERO, WITH EACH LINE ON
THE CONVERSION SCALE MARKING OFF (ONE/TWO) --- DEGREE(S).

(AWAY FROM, TWO)

WE CAN GENERALIZE, THEN, THAT A NINE-DEGREE
TEMPERATURE CHANGE IN FAHRENHEIT MEASURE IS THE SAME AS
A/AN --- DEGREE TEMPERATURE CHANGE IN CELSIUS MEASURE.

(FIVE)
THE TEMPERATURE RANGE OF A THERMOMETER IS EVEN MORE IMPORTANT THAN ITS SIZE AND SHAPE IN DETERMINING ITS USE.

FOR INSTANCE, A THERMOMETER WHICH MEASURES TEMPERATURES FROM 35 DEGREES CELSIUS TO 42 DEGREES CELSIUS WOULD LIKELY BE USED FOR -----.  

(BODY OR ORAL TEMPERATURES)

REFER TO VISUAL 4.

BOTH THE SHAPE AND TEMPERATURES LISTED ON THE THERMOMETER IN VISUAL 4 SHOULD INDICATE TO YOU THAT IT IS INTENDED TO MEASURE BODY TEMPERATURE.

NOTE THAT THE NUMBERS 6, 8, 9, AND 1 ACTUALLY REPRESENT 36, 38, 39, AND 41.

WHY IS THE NUMBER 37 OFTEN MARKED IN RED-----.  

(TO INDICATE NORMAL BODY TEMPERATURE)

WHERE WOULD YOU MOST LIKELY USE A THERMOMETER WHICH MEASURES FROM -25 DEGREES CELSIUS TO 10 DEGREES CELSIUS -----.  

(REFRIGERATOR OR FREEZER)
APPENDIX B

EVALUATION DEVICES
Congratulations! You have completed a self-instructional program on metric temperature. Your reactions to these teaching materials would be greatly appreciated. Check the appropriate item(s) that describe(s) your feelings about the program.

- too long
- interesting
- frustrating
- useful
- too much math
- fun
- rewarding
- too difficult
- too simple, boring
- recommend it to a friend
- too repetitious
- too brief, need more help

After completing this program on metric temperature, how much do you want to use your new knowledge in your daily life? Check one.

- not at all
- a little
- quite a bit
- a lot

How would you most prefer to learn the metric system? Check the three methods you most prefer.

- television
- newspapers
- movies
- textbooks
- correspondence course
- classroom (lecture & discussion)
- self-instructional program (like this)

Looking back on this course I feel. . . . (please complete)
Please fill in the following information:

Male ______  Female ______

Check with ______ the educational institutions you have attended:

_____ grade school  ______ four-year college
_____ high school  ______ graduate school
_____ junior college  ______ other (explain)
_____ vocational school

(Circle) the above institutions from which you graduated.

Check your age in the appropriate range below:

_____ under 14  ______ 36 to 45
_____ 14 to 18  ______ 46 to 55
_____ 19 to 25  ______ 56 to 65
_____ 26 to 35  ______ over 65

Please check your approximate high school class rank below:

Example:

[ ] Top 1/4
[ ] 2nd 1/4
[ ] 3rd 1/4
[ ] Bottom 1/4

____ Top 1/4 of class
____ 2nd 1/4 of class
____ 3rd 1/4 of class
____ Bottom 1/4 of class

____ Did not attend high school
Multiple choice: Approximate the following conversions, and write the number of the correct answer on the line provided. If your approximation is not within 10 degrees of the exact conversion given, mark 5. none of above.
3 points each

1. Freezers are generally set at 0°F. This is about
   1. -73°C
   2. -51°C
   3. -38°C
   4. -18°C
   5. none of above

2. The indoor swimming pool thermostat was set at 80°F or about
   1. 15°C
   2. 27°C
   3. 71°C
   4. 153°C
   5. none of above

3. Jane's cookies bake at 375°F. This is a metric temperature of about
   1. 158°C
   2. 191°C
   3. 258°C
   4. 315°C
   5. none of above

4. The bath water was too hot--nearly 140°F. It was approximately
   1. 12°C
   2. 33°C
   3. 60°C
   4. 62°C
   5. none of above

5. The dishwasher water was approximately 180°F or
   1. 110°C
   2. 154°C
   3. 219°C
   4. 300°C
   5. none of above
Use the conversion formulas to estimate the Celsius equivalents of these Fahrenheit temperatures. Write your answers on the lines provided. 3 points each (answers ±3)

<table>
<thead>
<tr>
<th>°C</th>
<th>°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>-8</td>
<td>18</td>
</tr>
<tr>
<td>155</td>
<td>310</td>
</tr>
<tr>
<td>21</td>
<td>72</td>
</tr>
<tr>
<td>186</td>
<td>366</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
</tr>
</tbody>
</table>

Approximate the following temperatures and write the Celsius temperatures on the lines provided. 3 points each (answers ±3 except for questions 14 and 19, ±10)

<table>
<thead>
<tr>
<th>°C</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Freezing water</td>
</tr>
<tr>
<td>37</td>
<td>Normal body temperature</td>
</tr>
<tr>
<td>41</td>
<td>Convulsions (body temperature)</td>
</tr>
<tr>
<td>10</td>
<td>Chilly fall day</td>
</tr>
<tr>
<td>46</td>
<td>Sizzling hot day or very sick</td>
</tr>
<tr>
<td>40</td>
<td>Point at which Celsius and Fahrenheit temperatures are the same</td>
</tr>
<tr>
<td>38</td>
<td>Low-grade fever (body temperature)</td>
</tr>
<tr>
<td>20</td>
<td>Room temperature</td>
</tr>
<tr>
<td>30</td>
<td>Thirsty summer day</td>
</tr>
<tr>
<td>100</td>
<td>Boiling water</td>
</tr>
</tbody>
</table>
Multiple choice: Write the number of the correct answer on the line provided. 3 points each

2 21. Terry is sick with a temperature rise of three degrees. The three-degree rise is
1. more serious if it is a rise of three Fahrenheit degrees.
2. more serious if it is a rise of three Celsius degrees.
3. the same degree of seriousness in Celsius and Fahrenheit measurements.

4 22. For every 5 degrees a Celsius temperature rises, a Fahrenheit temperature rises
1. 3 degrees
2. 5 degrees
3. 7 degrees
4. 9 degrees
5. none of above

1 23. Cookies are usually baked between 350°F and 375°F. This 25-degree Fahrenheit temperature range equals
1. a range of less than 25 degrees in Celsius measurement.
2. a range of 25 degrees in Celsius measurement also.
3. a range of more than 25 degrees in Celsius measurement.

Match the following temperature ranges with the kind of thermometer that would most likely be used to measure within the ranges given. Write the corresponding number (1-5) on the line left of the thermometer description. You may use the space to the right of the temperatures for approximating the Fahrenheit equivalents first. 4 points each

5 24. Indoor-outdoor thermometer

5 25. Oral (body) thermometer

1 26. Oven or candy thermometer

2 27. Indoor thermostat
1. 0°C to 360°C
2. 10°C to 35°C
3. -30°C to 50°C
4. -5°C to 10°C
5. 35°C to 42°C

Please go back and check to see that you have marked the correct answers.

Turn in this part of the post-test and pick up a copy of the second part and a conversion slide.
Use the conversion slide provided to figure the equivalents of the temperatures given below. Write your answers on the lines to the left of the questions. 3 points each (answers ±2)

WATCH OUT FOR NEGATIVE SIGNS, AND BE SURE TO USE THE SCALE CALLED FOR!!!

\[
\begin{align*}
-51 ^\circ C & \quad 28. \quad -60 ^\circ F \\
88 ^\circ C & \quad 29. \quad 190 ^\circ F \\
-44 ^\circ F & \quad 30. \quad -42 ^\circ C \\
66 ^\circ C & \quad 31. \quad 150 ^\circ F \\
246 ^\circ F & \quad 32. \quad 119 ^\circ C \\
\end{align*}
\]

Please go back and check to see that you have marked the correct answers.

This concludes the post-test.

Please fill out the attached "Sound Off" sheet. Your reactions and suggestions for this self-instructional program will be greatly appreciated. Thanks!!!
APPENDIX C

REGRESSION FORMULAS
REGRESSION FORMULAS

Formula A

\[ Y = 74.77 + 0.21X_1 + 2.84X_2 \]

where \( Y \) = predicted post-test score

\( X_1 \) = pre-test score

\( X_2 \) = relevance score (1, 2, 3 or 4)

1. not at all
2. a little
3. quite a bit
4. a lot

Formula B

\[ Y = 44.23 - 8.30X_1 + 4.45X_2 \]

where \( Y \) = predicted pre-test score

\( X_1 \) = sex (1 or 2)

1. male
2. female

\( X_2 \) = highest graduation attained (1, 2, 3, 4, 5, or 6)

1. grade school
2. high school
3. junior college
4. vocational school
5. four-year college
6. graduate school