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ABSTRACT

The purpose of this study was to investigate how the nature of metric estimation skill instruction affects prospective elementary and special education teachers' abilities to estimate metric length, area, and volume. Four types of estimation skills were identified by an estimation matrix. Three instructional strategies were selected: (1) a personal reference unit, (2) a cut or drawn unit of reference which was put out of sight before making an estimate, and (3) estimation without specifying an explicit strategy. The personal reference strategy was significantly more effective than the unit reference strategy for the estimation type that was the same as the instruction. (MK)

The Effects of Three Instructional Strategies on Prospective Teachers' Ability to Transfer Estimation Skills for Metric Length and Area[1]

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Introduction

Since the United States adopted the metric system as the principle system of measurement, changes have resulted in the education of inservice and preservice teachers in the measurement and estimation processes. Yet estimation skills continue to receive superficial treatment in the curriculum (Bright, 1976). The current research reveals that elementary inservice and preservice teachers lack adequate measurement and estimation skills (Swan and Jones, 1971; Corle, 1963). In the instructional activities focusing on estimation skills, the literature favors a hands-on approach (Bright, 1976; Swan and Jones, 1971; Corle, 1963; Spencer and Brydgaard, 1952).

The purpose of the investigation was to determine how the nature of the instruction in metric measurement and estimation skills affects prospective teachers' ability to estimate length and area in the metric system. Estimation was defined as the process of assigning a quantative value to a particular attribute without the aid of a measuring tool. In this investigation, the estimation process was conceptualized as represented by the cells in the matrix shown in Figure 1. Each cell in the matrix represents one of four types of estimation identified by Bright (1976) and Szabo and Trueblood (1976). Each type is defined based upon the absence or presence of the unit to be used in the estimation process and the absence or presence of the object to be estimated.

[1] A paper presented at the meeting of the National Association for Research in Science Teaching. Boston, April 1980.

UNIT of Reference To Be Used Is Physically	OBJECT To Be Estimated Is Absent	OBJECT To Be Estimated Is Present
	Type 1	Type 2
Absent	Object absent/unit of reference absent	Object present/unit of reference absent
	Type 3	Type 4
Present	Object absent/unit of reference present	Object present/unit of reference present

Figure 1. Matrix describing Estimation Types 1, 2, 3 and 4.

Hypotheses

It was hypothesized that the most efficient instruction for preservice teachers would result if a preservice teachers received instruction to criterion in one type of estimation skill (Type 2) and then were able to transfer that skill without additional instruction to the remaining types of estimation skills. The instructional phase of this investigation developed the preservice teachers' Type 2 estimation skills for length and area. As shown in Figure 1, Type 2 estimation skill is when the object to be estimated is physically present and the unit of reference to be used to do the estimation is absent. Type 2 was selected because it is most nearly like the estimation used in everyday situations.

Specifically, this investigation sought to determine the effects of preservice teachers' learning Type 2 length and area estimation skills to criterion on their ability to transfer Type 2 estimation skill to Type 1, Type 3, and Type 4 situations.

Design

State of the Problem

The ten hypotheses tested were related to two questions. First, of the three instructional strategies, does one instructional strategy result in a greater number of students mastering estimation skills for metric length and area? Second, what effect does explicit instruction to criterion for Type 2 estimation skills have on the ability to perform Type 1, 3 and 4 metric length and area estimation skills?

Instruction Strategies

Three instructional strategies were selected to teach estimation skills during this investigation. They were based upon a review of the related research and the literature (Bright, 1976; Spitzer, 1954; Gilbert and Gilbert, 1973). The three instructional strategies employed in this investigation were PR→ E→ M, UR→ E→ M and NSR→ E→ M. These strategies are defined as follows:

PR→ E→ M. An instructional strategy which requires the student to first state a personal reference measure to be used in making the estimate, then state an estimate of the object using the personal reference measure, and finally check the estimation accuracy by measuring the object.

UR→ E→ M. An instructional strategy which requires the student to first physically construct a reference unit by cutting or drawing, to check the accuracy of the reference unit; and after placing it out of sight, state an estimate of the object and finally check the accuracy of the estimate by measuring the object.

NSR→ E→ M. An instructional strategy that requires the student to first state an estimate of the object without using any specific reference unit, and check the estimation accuracy by measuring the object.

Selection of Students

One hundred twenty-six elementary and special education preservice teachers were the subject of this study. They were pretested to determine their ability to perform estimations for metric length, area and volume using a 60 item criterion referenced pretest. The pretest assessed the subject's ability to perform the four estimation types identified in Figure 1. Acceptable performance was defined as $\pm$ 15% accuracy on 60% of the item for each type of estimation skill. Since no students could estimate within this accuracy band, all of the subjects pretested were randomly assigned to one of the three instructional strategies.

Instructional Materials and Procedures

Consistent with criterion referenced instructional practices, three instructional modules were developed for this investigation. Module 1 taught the basic structure and content of the metric system and was completed by all students. Module 2 taught Type 2 length estimation skills and Module 3 taught Type 2 area estimation skills. Module 2 and Module 3 consisted of 3 separate parallel instructional episodes for each instructional strategy, PR→ E →M, UR→ E →M and NSR→ E →M.

After completing Module 1 all subjects were randomly assigned to complete episodes in Module 2 and Module 3. After completing each episode in Module 2 and Module 3 a student was given a five-item mastery test. The preservice teacher's estimates were evaluated to determine if they were within $\pm$ 15% of the measured value for 80% of the items. These results were used to decide whether each person received additional instruction on the same measurement attribute or whether their retention and transfer ability was tested using the retention and transfer test. Identical procedures were employed for Module 3.

Instrumentation

Specific objectives were developed for each module. A table of specifications was employed to develop items to test these objectives. Then a panel of science and mathematics educators, who have worked extensively with metric education, assessed the items to determine if they measured achievement of the specified objectives. Because of the nature of the four types of estimation skills, the order of assessment was improtant. Therefore, the estimation skills were assessed in chronological order so as not to reveal information to the student before it was called for by the estimation skill type. The mastery tests were scored using a ± 15/80% criterion. This criterion means that a preservice teacher's estimate had to be within ±15% of the measured value on 80% of their estimates. This yielded estimation error scores for each section of the pretests and retention and transfer test. The estimation error scores for each section were added to obtain a total score for each estimation type.

Findings

Comparative Efforts of the Instructional Strategies

Four specific hypothesis were tested in order to determine if differences existed in the number of students achieving mastery criterion for a given instructional strategy. The chi-square test for differences in proportion was used to test the four hypothesis stated below.

Hypothesis H1.1

> The proportion of students in PR→ E →M who demonstrate mastery of Type 2 length estimation skills will not differ significantly from the proportion of students in UR→ E →M who demonstrate mastery of Type 2 length estimation skills.

Hypothesis H1.2

> The proportion of students in PR→ E →M who demonstrate mastery of Type 2 length estimation skills will not differ significantly from the proportion of students in NSR→ E →M who demonstrate mastery of Type 2 length estimation skills.

Hypothesis H1.3

> The proportion of students in PR→ E →M who demonstrate mastery of Type 2 area estimation skills will not differ significantly from the proportion of students in UR→ E →M who demonstrate the mastery of Type 2 area estimation skills.

Hypothesis H1.4

The proportion of students in PR→ E→ M who demonstrate mastery of Type 2 area estimation skills will not differ significantly from the proportion of students in NSR→ E→ M who demonstrate mastery of Type 2 area estimation skills.

The personal reference strategy (PR→ E→ M) was compared to both the unit reference strategy (UR→ E →M) and the strategy which employed no specific strategy (NSR→ E →M). Data from the comparison is presented in Table 1.

Hypothesis H1.1, H1.2, H1.3, and H1.4 assessed the effectiveness of the instructional strategies in terms of the number of students who reached mastery criterion. The results indicate that under the conditions for this study, no instructional strategy was judged most effective in terms of the number of students who mastered Type 2 estimation skills. This means at the end of Module 2 and Module 3 neither PR →E →M, UR→ E →M, or NSR→ E →M instructional strategy was more effective than the other.

Changes in Estimation Error Scores Following Completion of Instruction

Current research does not reveal any attempt to classify the estimation process by the estimation types identified in Figure 1. Neither has there been any attempt to determine if instructional strategies which teach one type of estimation skill result in transfer to the remaining estimation skill types. Therefore, six hypothesis were formulated to test what effect explicit instruction to criterion for Type 2 estimation skill had on the ability to perform Type 1, 3 and 4 length and area estimation skills.

These hypotheses are:

H2.1

After mastering Type 2 length estimation skills using PR→E→M instruction, students Type 1, 3 and 4 length estimation skills will not significantly differ from their Type 1, 3, and 4 length estimation skills before instruction.

H2.2

After mastering Type 2 length estimation skills using <u>UR→ E →M</u> instruction, students' Type 1, 3, and 4 length estimation skills will not significantly differ from their Type 1, 3, and 4 length estimation skills before instruction.

H2.3

After mastering Type 2 length estimation skills using <u>NSR→ E→ M</u> instruction, students Type 1, 3, and 4 length estimation skills will not significantly differ from their Type 1, 3, and 4 length estimation skills before instruction.

H2.4

After mastering Type 2 area estimation skills using <u>PR→ E→ M</u> instruction, students Type 1, 3, and 4 area estimation skills will not significantly differ from their Type 1, 3, and 4 area estimation skills before instruction.

H2.5

After mastering Type 2 area estimation skills using <u>UR→ E→ M</u> instruction, students Type 1, 3, and 4 area estimation skills will not significantly differ from their Type 1, 3, and 4 area estimation skills before instruction.

H2.6

After mastering Type 2 area estimation skills using <u>NSR→ E→ M</u> instruction, students Type 1, 3, and 4 area estimation skills will not significantly differ from their Type 1, 3, and 4 area estimation skills before instruction.

Since assumptions of normality were inappropriate, the Wilcoxon Signed Rank Test was used to determine if there were significant differences in estimation error scores between the pretest scores and the estimation error scores on the Retention/Transfer test. The Wilcoxon which ranks scores gives greater weight to pairs of scores for a subject that show the greatest differences. Improvements in estimation error scores are indicated by negative rank changes. The results of their test are present in Table 2.

Investigation of the reduction in estimation error scores that occurred between the Pretest and the Retention/Transfer test can be obtained from the

Table 1

Comparison of Number of Students Achieving Mastery
For Each Instructional Strategy

Hypothesis	Groups Compared	Attribute	Number Achieving Mastery	Number not Achieving Mastery	Test Statistic using Chi Square
H1.1	PR→ E →M	Length	35	3	0.045
	UR→ E →M		33	3	
H1.2	PR→ E →M	Length	35	3	0.272
	NSR→ E →M		38	2	
H1.3	PR→ E →M	Area	26	5	0.095
	UR→ E →M		26	4	
H1.4	PR→ E →M	Area	26	5	0.756
	NSR→ E →M		24	8	

Table 2

Comparison of Estimation Error Score Before and Following Instruction for Students Who Demonstrated Mastery of Estimation Skills for Length and Area (Wilcoxon Signed Rank)

Hypothesis	Instructional Treatment	Attribute	Types of Estimation Skill: Type 1 (object and unit absent)	Type 3 (object and unit absent)	Type 4 (object and unit absent)
2.1	PR→ E →M (N=35)	Length	-4.791*	-1.436	-3.865
2.2	UR→ E →M (N=33)	Length	-4.833*	-0.813	-4.145
2.3	NSR→ E →M (N=36)	Length	-4.967*	-1.123	-4.430
2.4	PR→ E →M (N=26)	Area	-3.594*	-3/289*	-0.546
2.5	UR→ E →M (N=24)	Area	-2.686*	-3.343*	-0.800
2.6	NSR→ E →M (N=24)	Area	-2.686*	-3.343*	-0.800

*p <.05

date related to testing hypotheses 2.1, 2.2, 2.3, for length estimation skills and from 2.4, 2.5, and 2.6 for area estimation skills. For length estimation 92% of the prospective teachers who achieved mastery criterion on Module 2, for all instructional treatments showed significant reduction in estimation error scores for Type 1 and Type 4 length estimation skills. For area estimation skills, reductions were also noted in Type 1 and Type 3 area estimation skills.

The large reduction for Type 1 estimation skills is probably due in part to the nature of the testing conditions. Namely, students were not shown the metric units of the objects to be estimated. Thus the size of the initial estimation errors could be attributed to their unfamiliarity with the metric units. This has been observed by Swan and Jones (1971), Corle, (1963), Wilson and Cassell (1953) and Crawford and Zylstra (1952) in relationship to these same metric units.

Some students reported that they equated the meter with the yard, the decimeter with the foot and the centimeter with the inch. The use of the procedure seems to be reflected in the pretest data. Thus, students seem to do better when the metric and customary units were nearly the same in size.

Conclusions

At the beginning of the study there was a lack of hard data to support the use of a numerical value for estimation error. Instead of establishing a numerical value, the term "reasonably accurate" was most often cited in the literature when accuracy of estimation was discussed.

Since estimation is a process of arriving at a measurement without the use of a measurement instrument, reasonable allowances should be used when the estimation is not the same as the measurement. This investigation has shown ± 15/80% appeared to be "reasonable" given the size of the units used in this study. This conclusion is based upon the fact that an average of 93% of the preservice teachers were able to achieve this mastery criterion for length estimation and an average of 82% of the students were able to achieve mastery criterion for area estimation during the two weeks of instruction provided in this study.

Data from this investigation supports three other conclusions. First; the initial assessment of preservice teachers' metric estimation skills support previous research that shows preservice teachers lack adequate estimation skills vis-a-vis metrics. Thus, instruction for preservice teachers in metric length and area estimation is a necessity. This conclusion is supported by data that show none of the preservice teachers had sufficient estimation skills to warrant exemption from any of the instructional activities. Second, since 93% of the students demonstrated mastery of Type 2 length estimation skill and 82% of the students demonstrated mastery of Type 2 area estimation skill, the types of instructional activities used in this investigation could be used by other investigations in developing these skills. Third, transfer resulted from specific instruction in Type 2 estimation skills to Type 1, Type 3, and Type 4 estimation skills. This is supported by the results which show these skills improved without specific instruction.

The results further suggest that self-paced, criterion referenced metric measurement and estimation instruction similar to that used in the investigation is a viable teaching strategy. Therefore, this study may provide a basis for generating additional investigations in metric estimation skill development for preservice teacher.

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